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ENGINEERING DESIGN HANDBOOK

EXPLOSIVES SERIES
PROPERTIES OF EXPLOSIVES
OF MILITARY INTEREST

HEADQUARTERS, U.S. ARMY MATERIEL COMMAND

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ENGINEERING DESIGN HANDBOOK

PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

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PREFACE

The Engineering Design Handbook Series of the Army Materiel Command is a coordinated series of handbooks containing basic information and fundamental data useful in the design and development of Army materiel and systems. The handbooks are authoritative reference books of practical information and quantitative facts heipful in the design and development of Army materiel so that it will meet the tactical and technical needs of the Armed Forces.

AMCP 705-177, Properties of Explosive: of Military Interest, is one of a series on Explosives. One hundred and ten explosive compounds or mixtures are fisted herein, alphabetically, with their properties, including composition variations. These explosives were selected because of their current or probable application to military use.

The tabulated data reflect the results of tests, and were inst compiled for publication at Picatinny Arsenal, Dover, New Jersey, by M. R. Tomlinson, Jr. These data were later revised by Oliver E. Sheffield, also of Picatinny Arsenal. for the Engineering Handbook Office of Duke University, prime contractor to the Army Matamiel Command.

The Handbooks are readily available to all elements of AMC, including personnel and contractors having a need and/or requirement. The Army Materiel Command policy is to release these Engineering Design Handbooks to ther DOD activities and their contractors and to other Government agencies in accordance with current Army Regulation 70-31, dated 9 September 1966. Procedures for acquiring these Handbooks follow:

a. Activities within AMC and other DOD agencies order direct on an official form from:

Commanding Officer Letterkenny Army Depot, ATTN: AMXLE-ATD Chambersburg, Pennsylvania 17201

b. Contractors who have Department of Defense contracts should submit their requests through their contracting officer proper justification to the address listed in par. a.

c. Government agencies other than DLD having need for the Handbooks may submit their requests directly to the address listed in par. a or to:

Commanding General U. S. Army Materiel Command ATTN: AMCAM-ABS Washington, D. C. 20315

d. Industries not having Government contracts (this includes colleges and Universities) must forward their requests to:

Commanding General U. S. Army Materiel Command ATTN: AMCRD-TV Washington, D. C. 20315

e. All foreign requests must be submitted through the Washington, D. C. Embassy to:

Assistant Chief of Staff for Intelligence Foreign Liaison Office Department of the Army Washington, D. C. 20310

All requests, other than those originating within DOD, must be accompanied by a valid justification.

Comments and suggestions on this handbook are welcomed and should be addressed to Army Research Office-Durham, Box CM, Duke Station, Durham, North Carolina 27706.

ABBREVIATIONS AND SYMBOLS

```
approximately. This symbol is used before numbers.
۸C
                        Advisory Council on Scientific Research and Develop-
                        ment, Great Britain.
American Chemical Society.
American Tron and Steel Institute.
Liebig's Annalen der Chemie.
ACS
AISI
Ann
Ann chim phys
                        Annales de chimie et de physique.
                        armor-piercing.
Aberdeen Proving Ground.
APG
                        atmosphere; atmospheric pressure.
atz
                        Beilstein Organische Chemie, 4th Edition.
Berichte der Deutschen Chemischen Gesellschaft.
Beil
Ber
                        British Intelligence Overseas Service or Objective
Subcommittee, Group 2, Halstead Exploiting Center.
Bureau of Mines, United States Department of Interior.
BIOS GP2-HEC
BM
Bull Soc caim
                        Bulletin de la societé chimique de France. Chemical Abstracts.
CA
calc
                        calculated.
Cham Ket Eng
                        Chemical and Metallurgical Engineering.
                        Chimie et Industrie.
Comptes rendus hebdomadaires des geances de
Chim et Ind
Comp read
                               l'Academie des Sciences (Parie).
                        centipoise.
CP
CR
                        tomptes rendus hebiomadaires des seances de l'Academie des Sciences (Paris).
dec
                        decomposes.
                        difference in heat (i.e., heat evolved) by decomposition. Deutsches Reichspatent.
ΔH
DRP
                        Deutsches Reichspatent.
modulus of elesticity or "Young's modulus"; longitudinal
stress/change in length; (force/area)/(elongation/
length); expressed in lb/inch2.
same as 2, but expressed in dynes/cm2.
E
Gazz chim ital
                        Gazzetta Chimica Italiana.
                        general purpose.
high explosive.
high explosive antitank.
HE
HEAT
                        Industrial & Engineering Chemistry.

Journal of the American Chemical Society

The Journal of the Society of Chemical Industry (London).

Journal of the Chemical Society (London).
Ind Eng Chem
J Am Chem Soc
  Chem Ind
J Chen Soc
                        Journal of the Franklin Institute.
  Prank Inst
J Ind Explo-
sives Soc
J prakt Chem
                        Journal of the Industrial Explosives Society (Japan).
                        Journal für praktische Chemie.
                        lesd az'de
Land-Bornst
                        Landolt-Bornstein Physikalish-Chemische Tabellen,
                               5th Edition (Berlin).
                        Monatshefte für Chemie (Wein).
Kém pondr
                        Mémorial des poudres et salpêtres (Paris).
                        milligram.
```

ABBREVILTIONS AND SYMBOLS (cont'd)

```
sinimum.
min
                              milliliter.
ml
m/s
                             meters per second.
molecular weight.
Bureau of Ordnanco (U. S. Savy)
nitrocellulose.
MW
NAVORD
NC
n D 20
                              index of refraction, with D band of sodium as light
                              source, at twenty degrees centigrade.
National Defense Research Committee.
Hational Fireworks Ordnance Corporation.
MDRC
MYOC
                             nitr glycerin.
U. S. Maval Ordnance Laboratory, White Oak, Silver
MG
NOL
                              Spring, Maryland.
U. S. Haval Ordnance Test Station, China Lake, Calif.
Mational Research Council.
ROTS
NRC
OB
                              oxygen balance.
                              Ordnance Committee Minutes.
Office of Scientific Research and Development
OCH
OSED
                              Picatinny Arsenal.
Picatinny Arsenal Technical Report.
Philosophical Transactions of the Royal Society of
PA
PATR
Phil Trans
                             London.
Poggendorf's Annalen der Physik.
Proceedings of the Royal Society of London.
Recueil des travaux chimiques des Pays-Bas.
Pogs Ann
Proc Roy Soc
Rec trav chim
                              relative humidity.
Report of Investigation.
RH
RI
SAE
                              Society of Automotive Engineers.
                              semi-armor-piercing.
SAP
                              solution.
soi
Spec
std dev
                               Specifications.
Spec Specifications.

std dev standard deviation.

TM Technical Hanual, Department of the Army.

joint publication, as a TM and as a Department of the Air Force Technical Order.

Trans Farad Soc Transactions of the Faraday Society vacuum stability.
                              Zeitschrift für angewandte Chemie.

Leitschrift für anorganische und allgemeine Chemie.

Zeitschrift für das gesamte Schiess und Sprengstoff-

wessen (Munchen).
Z angew Chem
Z anorg Chem
Z ges Schiess-
   Sprengstofiw
                               atoms of oxyger per second.
```

PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

INTRODUCTION

1. PREDOMINATILY A REPORT OF STANDARD TESTS. No effort was made to cover all the existing literature, either open or classified security information, on any explosive. Sather, the main resource has been reports from facilities using standard of well-known test procedures.

2. ORIGIN. Compilation of data resulting in this handbook was undertaken by Picatinny Arsenal personnel who desired to provide a manual tabulating the characteristics of emplosives, based on tests, with regard to current, and possible future, interest. The first resulting Picatinny Arsenal publication was dated 20 June 1949. Revision 1, PA Technical Report No. 1740, dated April 1958, with revisions, provides the data used herein.

3. SCEPA. Tabulated data of tests on one hundred and ten explosive compounds or mixtures include sensitivity to friction, impact, heat; performance characteristics or effectiveness in weapons; physical and chemical properties; and method of preparation, synthesis or manufacture, with comments on historical origin, and supplementary references.

REFERENCE MOTATIONS AND SOURCES. The references, as to sources of data or for more details in methods of testing, have been listed, when available, at the end of each section devoted to a given emplosive compound, explosive mixture, or explosive ingredient. Where no reference is given, it can be assumed that these data represent typical values obtained by standard procedures. When available any reference should be consulted for more details in interpreting test data.

Also there are listed Picatinny Arsenal Technical Reports which contain **dditional information on the particular explosive. These report numbers are given in ascending order, in columns corresponding to their terminal digits, and in accordance with the "Uniterm Index" prepared for Picatinny Arsenal by Documentation Incorporated under Contract DAI-36-034-501-ORD-(P)-42 (1955).

5. EXPLANATION OF TERMS AND METRODS OF TESTING. Data are tabulated herein on three form-type pages, in the following sequence of headings. Many of these terms are self-explanatory.

a. First tabular page.

- (1) Name of the explosive in each instance.
- (2) "Composition."
- (3) "Impact Sensitivity, 2 Kg Wt."
 - (a) Impact sensitivity test for solids. (a)*

A sample (approximately 0.02 gram) of explosive is subjected to the action of a falling weight, usually 2 kilograms. A 20-milligram sample of explosive is always used in the Bureau of Mines (BM) apparatus when testing solid explosives. The weight of sample used in the Picatinny Arsenal (PA) apparatus is indicated in each case. The impact test value is the minimum

^{*}Reference publications (a through q), applying to this introduction, are listed at the end of the introduction.

neight at which ar least one of 10 trials results to exclusion. For the EM apparatus, the unit of height is the centimeter; for the PA apparatus, it is the inch. In the former, the explosive is held between two flat, parallel hardened (C 63 x 2) steel surfaces; in the latter case, it is placed in the depression of a small steel dis-cup, capped by a thin brass cover, in the center of which is placed a slotted-vented-cylindrical steel plug, slotted side down. In the held apparatus, the impact impulse is transmitted to the sample by the upper flat surface, in the PA, by the vented plug. The main differences between the two tests are that the PA test (1) involves greater confinement, (2) distributes the translational impulse over a smaller area (due to the inclined sides of the dis-cup cavity), and (3) involves a frictional component against the inclined sides).

The test value obtained with the PA apparatus depends, to a marked degree, on the sample density. This value indicates the hazard to be expected on subjecting the particular sample to an impact blow, but is of value in assessing a material's inherent sensitivity only if the apparent density (charge weight) is recorded along with the impact test value. The values tabulated harein were obtained on material screened between 50 and 100 mesh, U. S. Standard Screens where single component explosives are involved, and through 50 mesh for the mixtures.

(b) Impact sensitivity test for liquids. (b)

The PA Impact Test for liquids is run in the same way as for solids. The die-cup is filled and the top of the liquid meniscus adjusted to coincide with the plane of the top rim of the die-cup. To date, this visual observation has been found adequate to assure that the liquid does not wot the die-cup rim after the brass cap has been set in place. Thus far the reproducibility of data obtained in this way indicate that variations in sample size obtained are not significant.

In the case of the BM apparatus, the procedure that was described for solids is used with the following variations:

- 1. The weight of explosive tested is 0.007-gm.
- 2. A disc of desiccated filter paper (Whatman No. 1) 9.5-millimeter diameter; is laid on each drop, on the anvil, and then the plunger is lowered on the sample absorbed in the filter paper.
 - (4) "Friction Pendulum Test." (c)

A 7.0-gm sample of explosive, 50-100 mesh, is exposed to the action of a steel, or fiber, shoe swinging as a pendulum at the end of a long steel rod. The behavior of the sample is described qualitatively to indicate its reaction to this experience, i.e., the most energetic reaction is explosion, and in decreasing order of severity of reaction: snaps, cracks, and

(5) "Riffle Bullet Impact Test." (d)

Approximately 0.5-pound of explosive is leaded in the same manner as it is leaded for actual use: that is, east, pressed, or liquid in a 3-inch pipe nipple (2-inch inside diameter, 1/10-inch wall) closed on each end by a cap. The leaded item, in the standard test, contains a small air space which can, if desired, be filled by inserting a wax pluy. The leaded item is subjected to the impact of a caliber .30 bullet fired perpendicularly to the long axis of the pipe nipple, from a distance of 90 feet.

(6) "Explosion Temperature." (a)

A 0.02-gm sample (0.01-gm in the case of initiators) of explosive, loose loaded in a No. 8 blasting cap, is ammersed for a short period in a Wood's metal bath. The temperature determined is that which produces explosion, ignition or decomposition of the sample in 5 seconds, and the behavior of the sample is indicated by "Explodes" or "Ignites" or "Decomposes" placed beside the value. Where values were available for times other than 5 seconds, these have been included. For 0.1-second values, no cap was used, but the explosive was placed directly on Wood's metal bath, immediately after cleaning. The value 0.1 second is estimated, not determined, and represents an interval regarded as instantaneous to the observer's eye. Dashes indicate no action-

(7) "75°C International Heat Test." (a)

A 10-gm sample is heated for 48 hours at 75° C. The sample after this exposure is observed for signs of decomposition or volatility.

(8) "100°C Heat Test." (a)

A 0.6-gm sample is heated for two 48-hour periods at 100° C. It is also noted whether exposure at 100° C for 100 hours results in explosion.

(9) "Flammatility Index." (h)

The measure or the likelihood that there charge will catch fire when exposed to flames is the index of flammability. The test is made by bringing an oxyhydrogen flame to bear on the explosive. The maximum time of exposure which gives no ignition in 10 trials and the minimum exposure which gives ignition in each of 10 trials are determined. The index of flammability is 100 divided by the mean of the two times in seconds. The most flammable substances have high indices, e.g., 250.

(10) "Hygroscoricity."

A 5- to 10-gm sample is exposed for hygroscopicity under the stated conditions, until equilibrium is attained, or in cases where either the rate is extremely low, or very large amounts of water are picked up, for the stated time. The sample, if solid, is prepared by sieving through a 50 and on a 100 mesh screen.

(11) "Volatility."

A .3-gm sample is exposed for volatility under the stated conditions. The sample if solid is prepared by sieving through a 50 and on a 100 mesh sieve.

(12) "Molecular Weight."

The molecular weight (MW) of a mixture can be calculated from the equation

MV of mixture =
$$\frac{100}{\frac{8}{mv_1} + \frac{b}{mv_2} + \frac{c}{mv_3} + \frac{n}{mv_n}}$$

where a, b, c and s are the weight purcents of the components, and mv_1 , mv_2 , mv_3 and mv_n their corresponding molecular weights.

(13) "Oxygen Balance."

The caygon balance (OB) is calculated from the empirical formula of a compound in percentage of caygon required for complete conversion of carbon to carbon dioxide (or carbon monoxide) and hydrogen to water. When metal is present the reactions are assumed to occur in the following

Metal + 0
$$\longrightarrow$$
 Metal Oxide
C + H₂O \longrightarrow CO + N₂
CO₂ + H₂ \longrightarrow CO + H₂O
2CO + O₂ \longrightarrow 2CO₂

Procedure for valculating oxygen balance is to determine the number of gramatoms of oxygen which are excess or deficient for 100 grams of a compound. This number multiplied by the atomic weight of oxygen gives

the oxygen belance: 1600 (2X + $\frac{Y}{Z}$ - Z)

 \pm molecular weight of compound = oxygen balance to CO_2 and H_2O , where X = atoms of urbon, Y = atoms of oxygen. The oxygen balance of a mixture is equal to the sum of the percent composition times the oxygen balance for each component.

The cerbon/hydrogen (C/E) ratio is calculated as follows:

Number of C stone (\$C + \$H) = C/H ratio

- (14) "Density."
- (15) "Melting Point."
- (16) "Freezing Polat."
- (17) "Boiling Point."
- (18) "Refractive Index."
- (19) "Vacuum Stability Test." (a)

A 5.0-gm sample (1.0 gm for initiators), after having been carefully dried is heated for 40 hours, in vacuo at the desired temperature.

- (20) "200 Graz Bomb Sand Test."
 - (a) Sand test for solids. (a)

A 0.4-gm sample of explosive, pressed at 3000 pounds per square inch into a No. 6 csp, is initiated by lead azide, or mercury fulminate (or, if necessary, by lead azide and tetryl), in a sand test bomb containing 200 gm of "on 30 mesh" Ottawa sand. The amount of azide, or of tetryl, that must be used, to insure that the sample trushes the maximum net weight of sand, is designated as its sensitivity to initiation and the net weight of sand crushed, finer than

30 mesh, is termed the sand test value. The net weight of sand crushed is obtained by subtracting from the total the amount crushed by the initiator when shot alone.

(b) Sand test for liquid. (b)

The sand test for liquids is mak in accordance with the procedure given for solids except that the following procedure for locating the test samples is substituted:

Cut the closed end from a No. 6 blasting cap and load one end of the resulting cylinder with 0.20 gm of lead axide and 0.25 gm of tetryl, using a pressure of 3000 psi for consolidating each charge. With a pin, prick the powder train in one end of a piece of miner's black powder fuse 8 or 9 inches long. Crimp to the pricked end a loaded cylinder, taking care that the end of the fuse is held firmly against the charge in the cap. Crimp near the mouth of the cap so as to svoid squeezing the charge. Transfer a veighed portion of 0.400 gm of the test emplosive to an aluminum cap, taking precautions when the emplosive is liquid to insert the assume in such a manner that as little as possible adheres to the side walls of the cap, and when a solid material is being tested use material fine enough to pass through a No. 100 U. S. Standard Sieve. The caps used shall be of the following dimensions: length 2.00 inches, internal diameter 0.248-inch, wall thickness 0.025-inch. Press solid emplosives, after insertion into the aluminum cap, by means of hand pressure to an apparent density of approximately 1.2 gm per cubic centimeter. This was done by exerting hand pressure on a wooden plunger until the plunger had entered the cap to a depth of 3.93 centimeters. Following are the dimensions of the interior of the cap; height 5.00 cm, area of cross section 0.312 square centimeters. Insert the cylinder containing the fuse and explosive charge of tetryl and lead axide into the aluminum cap containing the test explosive for the determination of sand crushed.

(21) "Sensitivity to Initiation."

This is sensitivity to initiation as described under the preceding heading. The minimum detonating charge, in gress, required to detonate the explosive sample, is given.

(22) "Ballistic Mortar, % TNT." (e)

The amount of sample wider test which is necessary to raise the heavy ballistic mortar to the same height to which it is raised by 10 gm of trinitrotoluene (TNT) is determined. The sample is then rated, on a proportionate basis, as having a certain TNT value, i.e., as being a certain percent as effective as TNT in this respect. The formula is

The ballistic mortar consists of a long compound supporting rod, at the end of which is supported a heavy short-need mortar. The mortar contains a chamber about 6 inches in diameter and 1 foot long. A projectile occupies about 7 inches of the chamber and the sample to be tested occupies a small portion of the remainder of the chamber. When the sample is detonated, the projectile is driven into a sand bank, and the mortar swings through an angle which is marked on paper by a pencil attached to the mortar. The angle thus indicates the height to which the pendulum is raised by the explosion, and this latter represents the energy measured by this test procedure.

(23) "Trauzl Test, % TMT." (d)

A sample of the explosive to be tested (of the order of 10 gm) is exploded in a cavity, or borehole, 25-mm in diameter and 125-mm deep, in a lead block 200-mm in diameter and 200-mm in height. The borehole is made centrally in the upper face of each block, which is east in a mold from desilverized lead of the best quality. Although these tests have been made under a variety

of conditions, where possible the data have been taken from or related to those of Reference f (Maoum). Here a No. 8 blasting cap was used for initiation of the sample contained in glass. The weight of sample used was adjusted to give, with the initiator, a total expansion of 250 to 300 cc, since within this range expansion and sample weight were linearly related under the conditions - Maourn's test. Thus expansions for equivalent weights were readily calculated, and the test alue expressed in percent of the expansion of an equivalent weight of TNT.

(24) "Plate Dent Test." (d)

Two methods were used for plate dent tests.

- (a) Method A Ine charge is contained in a copper tube, having an internal dismeter of 3/4-inch and 1/16-inch wall. This loaded tube is placed vertically on a square piece of cold-rolled steel plate, 5/8-inch thick; 4-inch and 3-1/4-inch square plate gave the same results. The steel plate is in a herizontal position and rests in turn on a short length of heavy steel tubing 1-1/2 inches ID and 3 inches OD. The charge rests on the center of the plate and the centers of the charge, plate, and supporting tube are in the same line. A 20-gm charge of the explosive under test is boostered by a 5-gm pellet of tetryl, in turn initiated by a No. 8 detonator.
- (b) Method B A 1-5/8-inch diameter, 5-inch long uncased charge is fired on a 1-3/4-inch thick, 5-square inch cold-rolled steel plate, with one or more similar plates is backing. The charge is initiated with a No. 8 detonator and two 1-5/8-inch diameter, 30-gm tetryl boosters.

Plate dent test value, or relative brisance = Sample Dent Depth x 100.

(25) "Prioration Rate." (g)

The detonation rates reported in the tables contained herein were determined principally by using the rotating drum camera, under the conditions stated, e.g., usually charges 1 inch in diameter, 20 inches long, wrapped in cellulose acetate sheet, and initiated by a system designed to produce high order stable detonation at the maximum rate under the particular conditions. A typical initiating system for this consisted of four tetryl pellets 0.995 inch in diameter, 0.75 inch long, pressed to 1.50 gm/cc, with a Corps of Engineers special blasting cap placed in a central hole in the end pellet.

b. Second tabular page.

(1) "Booster Sensitivity Test." (p)

The booster sensitivity test procedure is a scaled up modification of the Bruceton method (unconfined charge). The source of the shock consists of two tetryl pellets, each 1.57 inches diameter by 1.60 inches high, of approximately 100 gm total weight. The initial shock is degraded through wax spacers of cast Acrawax B, 1-5/8 inches diameter. The test charges are 1-5/8 inches diameter by 5 inches long. The value given is the thickness of wax in inches at the 50% detonation point. The weight of tetryl pellet noted is the minimum which will produce detonation with the spacer indicated.

(2) "Heat of" (calorimetric tests). (i)

Heats of combustion and explosion are generally determined on samples weighing of the order of 1 to 2 gm, in standard calorimeter bombs such as the Parr or Emerson, approximately 400 cc: (for low loading density), or the Boas, approximately 45 cc (for high loading density). For

heats of combustion the sample is burned under about 40 atmospheres of oxygen; for heats of explosion, nitrogen, or one atmosphere of air is used.

- (3) "Specific Heat."
- (4) "Burning Rate."
- (5) "Thermal Conductivity."
- (6) "Coefficient of Expansion."
- (7) "Hardness, Mohs' Scale."
- (8) "Young's Modulus."
- (9) "Compressive Starreth."
- (10) "Vapor Pressure."
- (11) "Decomposition Equation."
- (12) "Armor Plate Impact Test." (j)
 - (a) 60-mm Mortar Projectile.

A modified 60-mm, N49A2, mortar projectile is loaded with the explosive to be tested, drilled to the proper depth (about 1/2 inch), and a flat-based steel plug screwed into the projectile to give a smooth close-fit between the plug base and the charge. The part of the plug outside the projectile is rounded off in the form of a spherical section. The loaded projectile with fins attached is fired from a five foot length of 2-3/8 inches ID x 3-3/8 inches OD Shelby steel tubing. The igniter and propelling charge, consisting of an igniter for a 2.36-inch rocket (besonka), 5 gm of 4F bl.ck power, and a quantity of shotgun propellant sufficient to give the desired velocity (read from a calibration chart) are conveniently loaded into the "gun" through a simple breech plug. The velocities are measured electronically, and the reaction, inert or affected, is determined by observation (e.g., whether or not flash occurs on impact). Within the range of flight stability of the projectile, 200-1100 ft/sec, the 50% point is located.

- (b) 500-1b General Purpose Bombs.
- (13) "Bomb Drop Test."

Bomb drops are made using bombs assembled in the conventional manner, as for service usage, but containing oither inert or simulated fuzes. The target is usually reinforced concrete.

c. Third tabular page.

(1) "Fragmentation Test." (1)

The weight of each empty projectile and weight of water displaced by the explosive charge is determined, and from this the specific gravity of the charge is calculated. All 3-inch and 90-mm projectiles are initiated by M2O Booster pellets, and those used with 3-inch HE. M42Al, Lot KC-5 and 90-mm HE, M71, Lot WC-91 projectiles are controlled in weight and height as follows: 22.50 \pm 0.10 gm, and 0.480 to 0.485 inch.

AMCP 766-177

The projectile assembled with fure, actuated by a Hasting Cap, Special, Type II (Spec 19-20) placed directly on a lead of comparable diameter and booster, are placed in boxes constructed of half-inch pine. The 90-mm projectiles are fragmented in boxes 21 x 10-1/2 x 10-1/2 inches and the 3-inch projectiles in boxes 15 x 9 x 9 inches outside diamesions. The box with projectile is placed on about 4 feet of sand in a seel fragmentation tub, the detorator wires are connected, and the box covered with approximately 4 feet more of sand. The projectile is fired and the sand run onto a gyrating 4-mesh screen on which the fragments are recovered.

(2) "Fregment Velocity."

Charges 10-1/8 inches long and 2 inches in diameter, containing a booster cavity, filled by a 72-gm tetryl pellet (1-3/8 inches diameter, 2 inches long, average density 1.594) are fired in a model projectile of Shelby seamless tubing, 2 inches ID, 3 inches OD, SAE 1020 steel, with a welded-on cold rolled steel base. The projectile is so fired in a chamber, connected to a corridor containing velocity stations, that a desired wedge of projectile casing fragments can be observed. The fragment velocities are determined by shadow photographs, using flash bulbs, and rotating drum cameras, each behind three slits. The drum cameras have a writing speed of 30 meters per second.

(3) "Blast (Relative to TNT)."

The blast pressures and impulses given were determined almost exclusively with tourseline gages, and the usual necessary specialized electrical circuits, shielded cc-axial cables, oscillographs, etc. In general, the data represent results of tests with large cased charges.

(4) "Shaped Charge Effectiveness, TRT = 100." (k, m)

Unconfined charges 2 inches in diameter and 5 inches long, boostered by a 10-gm pressed tetryl pellet, set in a 20-mm pellet (truncated come) of cast 60/40 cyclotol, are shot against 3-inch homogeneous armor plate at a 1-3/16 inches standoff. The comes used are commercial Pyrenglass funnels, sealed off at the start of the stem, 2 inches in diameter, 0.110 to 0.125 inch well thickness.

Unconfined charges 1.63 inches in dismeter and 6 inches long are tested at a standoff of 1.63 inches against stacks of $4 \times 4 \times 1$ inch mild steel plates. M9Al steel cones are used. Results are averages of 4 trials.

- (5) "Color."
- (6) "Principal Uses."
- (7) "Method of Loading."
- (8) "Loading Density."
- (9) "Storage."

Ammunition and bulk emplosives in storage represent varying degrees of hazard and compatibility. This has led to their being divided into a number of hazard classes and compatibility groups as indicated in subparagraphs (b) and (c) below.

- (a) Mathod: Wet or dry.
- (b) Hazard Class (Quantity-Distance).

Assumition and bulk explosives are divided into quantity-distance classes, Class 1 through 12, according to the damage expected if they explode or ignite (Reference: Army Material Command Regulation, ANCR 385-100, ANC Safety Namual, chapter 17). All standard explosives in bulk are included in four of these classes: Class 2, 2A, 9, and 12 (TM 9-1910/TO 11A-1-34).

(c) Corpatibility Group.

Explosives and assumition are grouped for compatibility with respect to the following factors:

- 1. Effects of explosion of the item.
- 2. Rate of deterioration.
- 3. Sensitivity to initiation.
- 4. Type of packing.
- 5. Effects of fire involving the item.
- 6. Quantity of explosive per unit.
- (d) Emdation.

d. Miscellaneous entries.

Where available and appropriate, the following or related data are given, in space at the bottom of the third form, or on plain pages.

- (1) Solubility.
- (2) Methods of manufacture.
- (3) Historical information.
- (4) Bulk compressibility modulus. (q)

The direct experimental measurement of the dynamic bulk modulus of a solid is difficult, and few such measurements have been made. One apparatus has been developed at the mayal Ordnance Laboratory and is described in detail in Reference q. Bulk modulus (its reciprocal is the compressibility) is defined as the ratio of stress to strain when the stress is a pressure applied equally on all surfaces of the sample and the strain is the resulting change in volume per unit volume.

· (5) Hydrolysis tests. (o)

The 240-hour hydrolysis test is conducted as follows: A 5-gm sample of the dry nitrocellulose is weighed accurately in a tare-weighed 250-oc Pyrex flask having a ground glass connection for a Pyrex condenser. Then 100 cc of distilled water is added to the nitrocellulose in the flask and the flask fitted to the condenser. The flask is placed in a steam bath in which the water is kept boiling constantly by means of electric hotplates. At the end of 240 hours the amount of solid developed by the hydrolysis of the nitrocellulose is measured by an electromatic pH method.

(6) Sensitivity to initiation by electrostatic discharge. (n)

The samples are tested under two amounts of confinement, designated as unconfined and confined. In the unconfined test, a sample of approximately 0.05 gm is dumped into a shallow depression in a steel block and flattened out with a spatula. In the confined tests (partly confined), the sample of approximately 0.05 gm is introduced into soft-glass tube (~7 mm ID x 18 mm long) which fits over a metal pag. The volume of the space around the charge at zero gap is ~0.15 cc; at a gap of 0.6 mm; it is ~0.4 cc. In addition to providing moderate confinement, this system also minimizes dispersion of the sample by the test spark, and reduces the effect of material being repelled from the needle point by electrostatic field effect.

When a test is to be made, the needle point electrode is screwed up until the gap between electrodes is greater than the critical gap discharge at the test voltage. The sample is then placed in position, the high-voltage terminal of the charged condensor is switched to the point electrode by means of a mercury switch, and the electrode is screwed down until discharge occurs.

The spark energy (in joules), for zero probability of ignition, is determined.

(7) Destruction by chemical decomposition.

Burning is the preferred method of destroying explosives. Initiating type explosives (in quantity) are usually destroyed by detourtion with demolition blocks. Destruction of explosives by chemical decomposition can be effectively used where small laboratory quantities are involved. Procedures given are standard for only lead axide, mercury fulminate and nitroglycerin.

- (8) Other information.
- (9) Ruferences.

6. REFERENCES CITED IN INTRODUCTION. 1

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- b. W. R. Tomlinson, Jr. and A. J. Clear, Development of Standard Tests -- Application of the Impact and Sand Tests to the Study of Mitroglycerin and Other Liquid Explosives, PATR No. 1738, 13 June 1949.
 - c. J. H. McIvor, Friction Pendulum, PA Testing Manual 7-1, 8 May 1950.
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 - i. Linnie E. Newman, PA Chemical Laboratory Report Nos. 127815 and 134476, 11 January 1951.
 - J. Report AC-2983/Org Expl 179.

Por information regarding source of references, inquiries should be made to the Commander, U.S. Army Research Office--Durham, ATTN: CRDARD-EH, Box CM, Duke Station, Durham, North Carolina 27706.

- k. Batern Labouatory, du Pont, Investigation of Cavity Effect, Section III, Variation of Cavity Effect with Composition, NIRC Contract W-672-ORD-5723.
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- m. Bastern Laboratory, du Pont, <u>Investigation of Cavity Effect</u>, Final Report, 18 September 1943, MIRC Contract V-572-ORD-5723.
- n. F. W. Brown, D. H. Kusler, and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Department of Interior, Bureau of Mines, R. I. 3852, 1946.
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- q. C. S. Sancler, An Acoustic Technique for Measuring the Effective Dynamic Bulk Mcdulus of Elasticity and Associated Loss Factor of Rubber and Plastics, MAVORD Report Sc. 1524, 1 September 1950.
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Amatol, 80/20

Oxygen Belence: CO: % +1 CO: % +1 Pensity: gm/cc Cast 1.46 Melting Point: "C	
Density: gm/cc Cast 1.46 Molting Point: "C	
Melting Point: 'C	
Provides Balaty IC	
Freezing Point: *C	
Belling Point: *C	
1	
n2 n2	
Vecuum Stability Test:	
cc/40 Hrs, at	
150°C 6.8	
Sand, gm 35.5	
Sensitivity to Initiation:	
1	
	
Trend Test, % TNT: (b) 123	
Place Bent Test: Method	
Condition	
Confined	
Density, gm/cc	
Brisance, % TNT	
Detenation Rate: Confinement None None	
Condition Cast Cast	
Charge Diameter, In. 1.0 1.0 Density, gm/cc 1.46 1.50	
	Refrestive Index, no.

C

Amatol, 80/20

agmentation Toot:	Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile, Let WC-91:	Glass Cones Steel Canes
Dunsity, gm/cc	Hole Volume
Charge Wt, Ib	Hole Dopth
Total No. of Fragments:	Celer: Buff-yellow
For TINT	Color: Buff-yellow
For Subject HE	Principal Uses: Bombs, RE projectiles
3 inch HE, MGZAT Projectile, Let KC-5:	Things our Buss, is projectizes
Density, gm/cc	
Churge Wit, Ib	
Total No. of Fragments:	Method of Londino: Cast
For TINT	Method of Looding: Chart
For Subject HE	
	Leeding Density: gm/cc 1.46
gment Velocity: ft/sec (f) At 9 ft 1900	
At 9 ft 1900 At 25 1/ ₂ ft 1750	Storege:
Density, gm/cc	
•	Method Dry
nt (Relative to TNT):	Hazard Class (Quantity-Distance) CLass 9
Alex	Compatibility Group Group I
Pecik Pressure	
Impulse	Exudation Does not exude at 65°C
Energy	
Air, Cantined:	Booster Sensitivity Test: (a)
Impulse	Condition Pressed
	Tetryl, gm 100
Under Weter: Pack Pressure	Wax, in. for 50% Detonation 0.83
Impulse	Density, gm/cc 1.65
Energy	Heat of: (d, e)
Undergrounds	Combustion, cal/gm 1002*
Peck Pressure	Explosion, cal/gu 490* Gas Volume, cc/gm 930*
Impulse	Gas Volume, cc/gm 930*
Energy	

Amatol, 60/40

Competition:		Melecular Weight:	100
		Oxygen Bolonce:	-
Ammonium Nitrate	50 40	CO ₂ %	-18
181	40	CO %	+ 2
		Density: gm/cc Cast	1.60
		Melting Point: *C	
C/H Ratio		Freezing Point: "C	·
Impact Sensitivity, 2 Kg Wt: Burrou of Mines Apparatus, cm	95	Bailing Point: *C	
Sample Wt 20 mg	92	Refractive Index, no	
Picatinny Arsenal Apparatus, in.	16	ng.	
Sample Wt, mg	17	-	
		n ₂₀	·
Friction Pandulum Test:		Vocuum Stability Test:	
Steel Shoe		cc/40 Hrs, at	
Fiber Shoe		90°C	
Riffe Suffet Impact Test: Trials		100°C	
%		120°C	
Explosions		135°C	•
Partials		150°C	
Burned		200 Grem Bomb Sond Test:	
Unaffected		Sand, gm	41.5
Explosion Temporature: "C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5 Decomposes 270		Lead Azide	0.20
10		Tetryl	0.06
15		B.M. A.	128
20		Ballistic Morter, % TNT: (a)	120
75°C International Heat Test:		Trousi Test, % TNT:	
% Loss in 48 Hrs		Plate Deat Test: Method	
100°C Heat Test:		Condition	
% Loss, 1st 48 Hrs		Confined	
% Loss, 2nd 48 Hrs		Density, gm/cc	
Explosion in 100 Hrs		Brisance, % TNT	
Flommobility ludex:		Detenation Rate:	
the state of the s		Confinemen	Yone
Hygreecepicity: %		Condition	Cast
···/g-cacopicay: 70		Charge Diameter, in.	1.0
Velotility:	Nil	Density, gm/cc	1.50
·	1417	Rate, meters/second	5760

Fregmentation Test:		Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile, Let \	WC-91:	Glass Cones Steel Cones
Density, gm/cc	1.49	Hole Volume
Charge Wt, Ib	1.971	Hole Depth
Total No. of Fragments:		
For TNT	703	Color: Buff-yellow
For Subject HE	583	District House and the second
3 inch HE, M42A1 Projectile, Let	KC-5:	Principel Uses: Bombs, HE projectiles
Density, gm/cc	1.57	
Charge Wt, Ib	0.827	
Total No. of Frequents:		Marked of London
For TNT	514	Method of Leading: Cast
For Subject HE	408	
		Leeding Density: gm/cc 160
Fragment Velocity: ft/sec At 9 ft At 251/4 ft		Storoge:
Density, gm/cc		
		Method Dry
lius! (Relative to TNT):	· · · · · · · · · · · · · · · · · · ·	Hazard Class (Quantity-Distance) Class 9
Ain		Compatibility Group Group I
Peak Pressure	95	7
Impulse	85	Exucation Does not exude at 65°C
Energy	84	
Air, Confined:		Heat of: (d, e)
Impulse		Combustion, cal/gm 1658*
<u> </u>		Explosion, cal/gm 633*
Under Weter:		Gar Volume, cc/gm 380*
Peak Pressure		
Impulse		
Energy		
Underground:		
Peak Pressure		
Impulse		` \
Energy		
		:
		MODI muladad dan ang atau
		*Calculated from composition of mixture.

Amatol, 50/50

Compositions	Melecular Weight:		118
₩	Guygen Balance:		
Ammonium Riffate 50	CO, %		27
THT 56	CO %		- 3
	Density: gm/cc ()	est	1.50
	Melting Point: *C		?
C/H Retio	Freezing Point: *C		
Impact Sandbirley, 2 Kg Wt:	Solling Point: *C		
Bureau of Mines Apparatus, cn: 95 Semple Wt 20 mg	Refractive Index, no		
Picatinny Arsenal Apparatus, in. 16			
Sample Wt, mg	nº		
	n <u>n</u>		
Folation Fendulum Test:	Vocuum Stubility Test:		
Steel Shoe Uneffected	cc/40 Hrs, at		
Fiber Shoe Unessected	90°C		
Rillo Bullet Impact Yest: Trials	100°C	٠	:0.2
%	120°C		1.0
Explosions 0	135°C		
Portiols 0	150°C		
Burned 0	200 Gram Bomb Sand Toor:		
Unaffected 100	Sand, gm		42.5
Explacion Temperature: 'C	Sensitivity to Initiation:		
Seconds, 0.1 (no ccp used)	Minimum Detonating Ch	orge, gm	
1 2	Mercury Fulminate		
5 Decompos as 265	Lead Azide		0.20
10	Tetryl		0.05
15 20	Balliotic Mortor, % TNT:	(e)	124
	Trough Test, % THT:		
75°C International Most Test: % Lass in 48 Hrs	Plate Dent Test:		_
	Method		В
180°C Heat Test:	Condition		Cast
% Loss, 1st 48 Hrs	Confined		No
96 coss, 2nd 48 Hrs	Density, gm/cc		1.55
Explosion in 100 Hrs	Brisance, % TNT		52
Floranshillty Index:	- Detenation Rate:		_
Fuciamentally States:	Confinement	None	None
Hygreecopicity: % N11	Condition	Cost	Cast
mygracepany: 70	Charge Diameter, in.	1.0	1.0
Volatility:	Density, gm/cc	1.55	1.55
- american	Rate, meters/second	6430	6230

Amatol, 50/50

regressionien Test:		Shaped Charge Effectiveness, TNT = 100:	
90 mm KE, M71 Projectile, Le	t WC-91;	Glass Cones Steel Cones	(g)
Density, gm/cc	1.55	Hole Volume 53	
Charge Wt, Ib	2.053	Hole Depth 69	. -
Total No. of Fragments:			
For TNT	703	Color: Buff-ye)low	
For Subject HE	630		
3 Inch HE, MASA1 Projectile, L	a KCS:	Principal Vess: Bombs, HE projectiles	*
Density, gm/cc	1.54	ì	<i>;</i>
Charge Wi, ib	0.819		
Total No. of Fragments:	•		,
For TNT	514	Method of Looding: Cast	
For Subject HE	385		
		Leading Bessity: gm/cc 1-59	
agment Velesity: ft/sec At 9 ft			
At 251/4 ft		Sturnge:	
Density, gm/cc		Method Dry	(
est (Relative to TNT):	·	Hozord Class (Quantity-Distance) Class 9)
Ain		Compatibility Group Group I	:
Peak Pressure	91		
Impulse	87	Exudation Does not exude at 65°C	
Energy		` `	
Al- C-C-4		Booster Sensitivity Test: (a	
Alr, Confined: Impulse			ist 10.
			60
Under Weter:	4	Density, gm/ce	
Peak Pressure		Heat of:	l. e)
Impulse		Combustion, cal/gm 19	
Energy	93		103 * 155*
Underground:		*Calculated from composition of mixtu	re.
Peak Pressure	104	Specific Heat: cel/gm/°C (i)	
Impulse	104	Temp, 20° to 80°C 0.	363
Energy	104	Bomb Drop Test: T7, 2000-1b Semi-Armor-Piercing Bomb vs Concrete:	
		Hax Safe Drop, ft. 4000-	5000

Compatibility with Merals:

May - Metals unaffected are sinc, iron, tin, braus, brass tin plated, brass RRC coated, brass shellac coated, nickel aluminum, steel, steel plated bith nickel, sinc or tin, stainless steel, Parkerized steel, and steel coated with acid-proof black paint. Metals slightly affected are copper, bronze, lead and copper plated steel.

Preparation:

In preparing amatols the proper granulation of amonium nitrate is required if the eximum density of the cost amatol is desired. The ammonium nitrate should be dried so as to contain not more than 0.25% moisture. It should be heated to about 90°C before being added to the appropriate weight of molten TNT contained in a melting vessel equipped with an agitator. Contained in the shall or bombs.

Origin:

Developed by the British during world War I in order to conserve TNT.

References: 2

- (a) L. C. Smith and B. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSED Report 5746, 27 December 1945.
 - (b) Report AC-17/Phys Ex 1.
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- (e) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, MAVORD Report No. 87-46, 26 July 1946.
- (f) R. W. Drake, <u>Pragment Velocity</u> and Panel Penetration of Several Explosives in Simulated <u>Shells</u>, OSRD Report No. 5622, 2 January 1946.
- (g) Eastern Laboratory, du Pont, <u>Investigation of Cavity Effect</u>, Final Report, 18 September 1943, NDRC Converet W-672-ORD-5723.
 - (h) Also see the following Picatinny Arsenal Technical Reports on Amatols:

<u>o</u>	1	2	3	<u>4</u>	<u> 2</u>	<u>6</u>	7	8	2
240 350 630 950 1300 1530	681 731 901 1051 1311 1451 1651	132 182 1302 1352 1372 1552	743 1173 1373 1323 1493 1763	364 694 734 874 1344	65 425 695 715 735 1145 1245 1345 1455 1885	266 556 666 986 1376 1446 1636 1796	1207 1457 17-7 1827 2167	54-8 638 838 1098 1148 1388 1568 1838	549 799 929 1129 1219 1369 1559

(i) TM 9-1910/TO 11A-1-34, Military Explosives, April 1955.

²See footnate 1, page 10.

Amages]

Composition	Makingthe Weight: 102
Amonium Nitrate 22 SRI 67 Aluminum 11	Oxygen Balence: CO, % CO % -22
	Daniel gm/cc Cest 1.65
	Melting Politic C
C/H Ratio	Property Points C
Im act Venility by, 2 Kg WI:	Boiling Peint: C
Bureau of Mines Apparatus, cm 91 Same e W 20 mg Picatinny Arsenal Apparatus, in. 11 Semple Wt, mg 19	Refroetive Index, no. no. no.
Fri-tion Pandurum Tast: Start Shoe Fiber Shoe	Version Stability Tea: cc/40 Hrs, at 90°C
Rifle Bullet (sepect Test: Trials 96 Explosions Partials	120°C 4.4.4.150°C
Burnod Unaffected	300 Grem Ramb Sand Test: Sand, gm h7.8
Explosion Temperature: *C Seconds, 0.1 (no cap used) 1 5 Decomposes 265	Sensitivity to Initiation: Minimum Detonating Charge, grn Mercury Fulminate Lead Azide Tetryl
15 20	Ballistic Morter, % TNT: (a) 122
	Treuxi Test, % TNT:
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Tesi: Method
100°C Hoot Toot:	Condition Contined
% Loss, 1st 48 Hrs 0.00	Density, gm/cc
% Loss, 2nd 48 Hrs 0-10 Explosion in 100 Hrs None	Brisance, % TNT
Flammebility Index:	Detenution Rete: Confinement
Hygrescapicity: %	Condition Charge Diameter, in.
	Density, gm/cc

Ammona 1

Progmontation Test:		Shaped Cherge Effectiveness, TNT == 100:
90 mm HE, M71 Projectile, Let V	VC-91:	Gloss Cones Steel Cones
Density, gm/cc		Hole Volume
Charge Wt, to		Hole Depth
Total No. of Fragments:		
For TNT		Colors
For Subject HE		Dischart these Protection (NY)
3 inch HE, M42A1 Projectile, Lut	KC-5:	Principal Uses: Projectile filler
Density, gm/sc	1.65	
Charge Wt, Ib		
Total No. of Fragments:		Marked of headhan
For TINT	655	Method of Leading: Cast
For Subject HE	550	Leeding Density: gm/cc 1.65
Fragment Valority: ft/sec		1.85
At 9 ft At 25½ ft		Storage:
Density, gm/cc	-	
		Method Dry
Bleet (Religitive to TNT):		Hazord Class (Quantity-Distance) Class 9
Ain		Compatibility Group
Peak Pressure		Frankskan
Impulse		Exaderion
Energy		
Ale, Confined:		Origin:
impulse		Castable mixture developed in United State during World War I.
Under Weter:		
Peak Pressure		References:
Impulse Samuel		(a) W. R. Tomlinson, Jr., Physical and Explosive Properties of Military Explosives,
En igy		PATR No. 1372, 29 November 1943.
Underground:		(b) Also see the following Picetinny Ar-
Peak Presture	*	senal Technical Reports on Ammonals: 1108,
Impulse Second		1286, 1292, 1308 and 1783.
Energy		
Preparation:		
Procedure same as describe except aluminum is added to trate-INT molten mixture und til uniformity in compositional in accomplished by processing is accomplished by the complished by the complex c	the ammonium ni- der sgitation un- on is obtained.	

Armonium Mitrate

Composition:			Meisenter Weight: (B _i X	203)	80
H 35	,	:	Oxygen Belense: CO: % CO %		+20 +20
H 5	•	MB, MO	Benelty: gm/cc Crysts	1	1.73
0 60			Making Point: °C		170
C/H Ratio			Freezing Point: *C		
Impact Sensitivity, 2 Kg W			Boiling Point: *C		· · · · · · · · · · · · · · · · · · ·
Bureau of Mines Apparo Sample Wt 20 mg Picatinny Arsenal Appar Sample Wt, mg		100+ 31 17	Refrestive index, ng ng ng		
Printies Pendelum Test: Steel Shoe Fiber Shoe	Unaff Unaff		Vecum Stability Test: cc/40 Hrs, at 90°C		
RMo Bullet Impact Test:	Trials		100°C		0.3 0.3
P bankan	%		135°C	•	
Explosions Partials	0		150°C		0.3
Burned Unaffected	0		200 Graw Bemb Sand Text: Sand, gm	,	E1
Explosion Temperature: Seconds, 0.1 (no cop us 1 5 Ignites 10	•C ed) 465		Sensitivity to Initiation: Minimum Detonating Ch Mercury Fulminate Lead Azide Tetryl	oarge, gm	0-20 0-25
15			Sallistic Morter, % TNT:	(a)	56
20			Trougi Test, % TNT:	\ - /	
75°C International Heat To % Loss in 48 Hrs	st: (a)	0.0	Plate Dent Test: Method		
100°C Heat Test:			. Condition		
% Loss, 1st 48 Hrs		0.74	Confined		
% Loss, 2nd 48 Hrs		0.13	Density, gm/cc		
Explosion in 100 Hrs		None	Brisance, % TNT		
			Condition	(b) None Solid	Strong Liquid
Flammability Index:					1.700170
Hygrecopicity: % 30°C, 90% RH		Extreme	Charge Diameter, in. Density, gm/cc	1.25	4.5 1.4

Ammonium Mitrate

Secretar Semplifyity Tests	Decomposition Squatten: (f) Chygen, otoma/sec 1013.8 (h) 1012.3
Condition	Crygen, etems/sec 10 ^{13.0} 10 ^{12.3}
Tetryl, gm.	Heat, kilocolorie/mole 40-5 38-3
West, In. for 50% Detanation	(AH, kcol/mol)
Wax, gm	Temperature Range, *C 243-261 217-267
Density, gm/cc	Phase Idenia
Heat of:	Armor Plate Impact Test:
Combustion, cal/gm 346	
Explasion, cel/gm 346	60 mm Morter Projectile:
Gas Volume, cc/gm 980	50% Inert, Velocity, ft/sec
Formation, col/gm 1098	Aluminum Fineness
Fusion, cal/gm 18.23	SOO-Ib General Purpose Bombe:
Specific Heat: col/gm/°C (e)	,
o _C o _C	Plate Thickness, inches
-150 0.189 0 0.397 -100 0.330 50 0.412	
-100 0.330 50 0.41% -50 0.364 100 0.426	114
200 01.125	11/4
	192
Burning Rate:	
cm/sec	Semi- Dres Test:
	same oray tar:
Thermal Conductivity: col/sec/cm/°C 2.9-3.9 x 10 ⁻⁴	T7, 2006-16 Semi-Armor-Plorcing Somb vs Concrete:
Coefficient of Expension:	Max Safe Drop, ft
Linear, %/°C	500-lb General Purpose Bomb vs Cuscrete:
Volume, %/°C	Height, ft
	Trials
Hordness, Mohe' Scale:	Unaffected
Maria Alai Alai Alai	Low Order
Young's Modulus:	High Order
E', dynes/cm²	
E, lb/inch²	1060-lb General Purpose Bomb v. Concrete:
Density, gm/cc	Height, ft
Compressive Strength: Ib/inch²	Trials
acting to the state of the stat	Unaffected
Y 1	Low Order
Vapor Pressure: (g) *C mm Mercury	High Order
188 3.25	Congression and Section 2
205 7.45	
21 6 11.55	
223 15.80 236 21:8	

Ammonium Mitrate

Prognontation Test:	Shaped Charge Effectivelets, TNT == 100:					
90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hale Valume Hale Depth					
Total No. of Fragments: For TNT	Color: Colorles»					
For Subject HE 3 Inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: Explosive ingredient of mixtures used in bombs or large caliber projectiles					
Total No. of Fragments: For TNT For Subject HE	Mushed of Leeding: Pressed or cast depending on composition of mixture					
Fregment Velocity: ft/sec At 9 ft At 251/s ft Density, gm/cc	Storage: Method Dry					
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) CLASS 12					
Air: Peak Pressure Impulse Energy	Compatibility Group Group D Exudation Name					
Air, Confined: Impulse	Effect of Temperature on Impact Sensitivity (Chemically pure grade): (b)					
Under Water: Peak Pressure Impulse Energy Underground:	Temp. PA Impact Test OC 2 Kg Wt, inches 25 31 75 28 100 27 150 27 175 12					
Peak Pressure Impulse Energy	Compatibility with Metals: (a) In the presence of moisture, ammonium nitrate reacts with copper, iron steel, brass, lead and cadmium.					
	Entropy: (g)					
	cal/mol at 25°C 36.0					

Ammonium Mitrate

Solubility of emcaium nitrate, grame in 100 grams (\$) of: (e)

<u> 14</u>	ter	Alo	opoj	Acet	lc Acid		Mitric	Acid	Py	ridine
888889	118 198 198 1997 421 580 871	°C 20 40 60 78	2.5 5 7.5 10.5	°C 16.6 27.0 80.9 101.0 120.0	5.0 0.39 5.8 20.7 125	°c 0 15 30 75	\$5.1 73.0 106 201	Acid 30.0 21.7 20.8 31.6	°ু হ	~জন্জ

Preparation:

Ammonium nitrate is prepared by the neutralization of an aqueous solution of ammonia with nitric acid and evaporation of the solution. The product which is very pure is dried in a graining kettle.

Origin:

First prepared by Glauber in 1659 and first used as an explosive ingredient in 1867 when a Swedish patent was granted to Chlason and Morrbin for a composite dynamite.

Destruction by Chemical Decomposition:

Associum nitrate is decomposed by strong alkalies with the liberation of associa, and by sulfuric acid with the formation of associum sulfate and nitric acid.

References:

- (a) Departments of the Army and the Air Force TM 9-1910/TO 11a-1-34, Military Emplosives, April 1955.
- (b) P. F. Macy, T. D. Dudderar, E. F. Reese and L. H. Eriksen, Investigation of Sensitivity of Fertilizer Grade Associus Mitrate to Explosion, PATR No. 1658, 11 July 1947.
 - (c) D. P. MccDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
 - (e) International Critical Tables, McGraw-Hill Book Co., N. Y., Land-Bornst.
- G. D. Clift and B. T. Federoff, A Manual for Explosives Laboratories, Vol. II, Lefax Society, Inc., Philadelphia, 1943.
- (f) R. J. Pinkelstein and G. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.
- (g) George Peick, The Dissociation Pressure and Free Energy of Formation of Ammonium Mitrate, Arthur D. Little, Inc., J Am Chem Soc, 76, 5858-60 (1954).
- (h) M. A. Cook and M. Taylor Abegg, Isothermal Decomposition of Explosives, University of Utah, Ind Eng Chem, June 1956, pp. 1090 to 1095.

³See footnote 1, page 10

perconium Mitrate

AMCP 706-177

(1)	WITEO MEG	cale zorrow	Tif Lione	TIM VINE	met facilit	TOST Wabo	138 OH FA	monton 47	W # 0# !
, Q.	1	2	3	, 4	2	<u>6</u>	I	8	2
250 630 1290 1720	731 1351 1241		743 1323 1763 2183	364 984 1094 1214 1234 1304	695 1145 1225 1455 1635 1675 1725	596 666 676 946 1106 1696	907 1117 1947 2167	548 638 938 1008 1038	799 1 369 1409

Ammonium Perchlorate

Compention:	Melecular Weight: (CLELNO)	117.5
% 0.8 11.9	Oxygen Belease: CO ₂ % CO %	+27.3 +27.3
ME, CLO,	Dunelty: gm/cc	1.95
3.4	Malting Point: *C	
0 54.5 C/H Ratio	Principle Telent: °C	
Impact Spelitity, 2 Kg Wt:	Beiling Points *C	
Sample Wt 20 mg Picetinm, Areenal Apparatus, in. 24 Sample Wt, mg. 24	Refrective Index, no.	
Frieties Fundulum Test:	Vuccinum Stebility Test:	
Steel Shoc Bnaps Fiber Shoe Uncerted	cc/40 Hrs, at 90°C	
Riffe Bellet Empect Tests Trials	100°C	0.13 0.20
%	135°C	
Explosions Portiols	150°C	0.32
Burned Unaffected	290 Grem Bomb Sand Yest: Sand, gre	6.0
Explosion Temperature: "C	Secultivity to Initiation:	and the second s
Seconds, 0.1 (no cop used)	Minimum Detonating Charge, gm	, \$ t - 1
1 5 435	Morcury Fulminate	,
10	Lead Axide Tetryl	0.20 0.25
15		U-2)
20 () () () () () () () () () (Ballistic Mortor, & TMT:	
	Toward Tost, % TN":	
75°C International Heat Text; % Loss in 48 Hrs	Plate Dent Test: Mathed	
160°C Heet Yest:	Condition	
% Loss, 1st 48 Hrs 0.02	Confined	e e e e e e e e e e e e e e e e e e e
% Locs, 2nd 48 Hrs 0.00	Density, gm/cc	
Suplosion in 100 Hrs Rone	Brisance, % TNT	
Flammability Index:	Detanation Rate: Confinement	
Hygrescopicity: %	Condition Charge Diameter, in.	
	Density, gm/cc	

Assonium Perchlorate

V 6000	
Progmostatica Tests	Shoped Charge Effectiveness, THT = 190:
90 mis Mt, M71 Fregratte, Lat WC-91:	Gloss Cones Steel Cores
Cancilly, gen/cc	Hole Volume
Constitution of the second	Hole Depth
Tabai bin. / Journales	
For TNT	Gebet Colorless
For Subject HE	
	Principal Usus: Explosive ingredient of
3 hab Pts, MIZAT Projection, Let MC-3:	mixtures used in pyrotochnics and
Jenetty, gan/a	as projectile filler
Charge Wt. St.	
Total No. of Programatic	Method of Leading: Pressed or cast depending
INT INT	on composition of mixture
For Subject ISE	
	Leeding Density: gm/cc Variable
Programma Velically: ft/sec.	
À9A	
Ar 25% ft	Steregit 1
Density, grn/cc	
	Methos Dry
Blant (Exhative to TNT):	Hazard Class (Quantity-Distance) Class 9
	Tractic diagrams, 2 Marion, 2 Marion
	Compatibility Group
Peak Pressure	
Impulse	Exudatic None
Energy	
	Solubility in Water
Ale, Graffinger	gm/200 cc saturated solution;
Impulse	
Value Weter:	2)°C 20
Peak Prosume	60°C 39
Impulse	100°C 88
Energy	Present stand
	Prepasition:
Undergreand:	The perchlorates are prepared by the action
Peak Pressure	of the acid on a suitable base; by the ther-
Impulse	mal decomposition of certain chlorates; and by the electrolysis of chlorates (see origin).
Energy	by the electron are of colorates (see origin).
	Heat of:
* .	Formation, cal/gm 665

Ammonium Perchlorate

Origin: (c)

2. Mitscherlich first prepared, in 1832, crystals of amsonium perchlorate from barium perchlorate and amsonium sulfate (Pogg Ann 25, 300). T. Schlosing treated a hot solution of setium perchlorate with amsonium chloride, and on cooling, crystals of amsonium perchlorate were obtained (Comp rend, 73, 1269, [1871]). U. Alvisi treated a mixture of 76 parks of amsonium nitrate with 213 parts of sodium perchlorate, and obtained a crop of small crystals of amsonium perchlorate taken were purified by recrystallization from hot water (German Patent, 103,993, 7896). A. hiolati mixed magnesium or calcium perchlorate with amsonium chloride and crystals of amsonium perchlorate deposited from the solution of very soluble magnesium or calcium chloride (German Patent, 112, 682, 1899).

References: 4

- (a) W. B. Tomlinson, Jr., <u>Physical and Explosive Properties of Hilitary Explosives</u>, PATR Bo. 1372, 29 November 1943.
- (b) T. L. Davis, The Chemistry of Powder and Explosives, John Wiley and Sons, Inc., New York, 1943.
- (c) J. W. Mellor, A Comprehensive Treatise on Inorganic and Theoretical Chemistry, Vol. II, Longanums, Green and Co., London, 1982, p. 396.
 - (d) Also see the following Picatinny Arsenal Technical Reports on Ammonium Perchlorate:

<u>o</u>	1	C.E. 3	4	5	<u>6</u>	2
100	521	8 ¹ 43 1783	354 60 4 854	1095 1725 2205	1726	1 0 49 1969

See fontnote 1, page 10.

Baratol

Composition: %	Molecular Weight:	125
•	Oxygen Belence:	
Barium nitrate 67	CO ₂ %	-3
TNT 33	CO %	+13
	Density: gm/cc Cast	2.55
	Melting Point: °C	
C/H Ratio	Freezing Point: *C	
Impact Sonsitivity, 2 Kg Wt:	Boiling Point: °C	
Bureau of Mines Apparatus, cm 35 Sample Wt 20 riig	Refractive Index, no	
Picatinny Arsenal Apparatus, in. 11	_	
Somple Wt, mg 24	n _m	
	n <u>∞</u>	
Friction Pendulum Test:	Vocuum Stability Test:	
Steel Shoe	cc/40 Hrs, at	
Fiber Shoe	90°C	
PMI Pulled Investor Total		•
Rifle Bullet Impact Test: Trials	120°C	
Explosions %	135°C	
Portials	150°C	
Surned		
Unaffected	200 Gram Bomb Sand Test:	
Ordifected	Sand, gm	26.8
Explosion Temperature: °C	Secretivity to Initiation:	*
Seccids, 0.1 (no cap used)	Minimum Detonating Charge, g	m .
1	Mercury Fulminate	
5 Ignites 385	Leod Azide	0.20
10	Tetryl	0.10
15		
20	Ballistic Mortar, % TNT:	
75 C International Heat Test:	Trauxi Test, % TNT:	
% Loss in 48 Hrs	Plate Denii Test: (a) Method	73/27 B
103°C Heat Test:	Condition	Cast.
% Loss, 1st 48 Hrs	Confined	No
% Loss, 2nd 40 Hrs	Density, gm/cc	2.52
Explosion in 100 Hrs	Brisance, % TNT	ϵ_1
	Detonation Rate:	
Flammability Index:	Confinement	•
	Candition	
Hygroscopicity: %	Charge Diameter, in.	
30°C, 90% NI	Density gm/cc	
Volatility:	Rate, meters/second	

£.

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Barutol

Bosotor Sensitivity Test:	Discompanition Equilies:
Condition	Oxygen, econsises
Tetryl, gm	(Z/sec)
Wex, in. for 50% Defonation 0.32	Heat, kilocolorie/mole (AH, kcal/mol)
Wax, gm	Temperature Ronge, *C
Density, gm/sc 2.55	
	Phiss 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Next of:	
Combustion, cal/grn	Armie Plate Impact Test:
Explanion, cai/gm	60 mm Martur Cor scilles
Gas Volume, carpm	\$3% mert, Velocity, ft/sec
Formation, cal/gm	Aluminum Finances
Fesion, col/gm 75/25 Bers tol 2.8 (d)	
	500-lb General Purpose Bombs:
ipecific Heet: coi/gm/*C (8) 75/25 Baratol	
	Plate Thickness, triches
	THE THEOLOGIA, HIGHES
-75 0.152 75 0.280	
0 0.147 85 0.213	
25 0.160 90 0.201	
50 0.229 100 0.171	1½ ~ (第二) (14. 1) (A. 1) (A. 1) (A. 1) (A. 1)
	1 1944 J. 184
lureling Rote:	
cm/yec	
	Bomb Drop Text: Kyen in figure (CC) (Sp. 426)
Thermal Conductivity:	14.5° (14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 1
col sec/cm/°C	37, 2000-16 Semi-Arzoer-Planting Bomb vs Conspetts:
THE STATE OF THE S	
Coefficient of Exponsion:	Max Safe Drop, ft
Linear, %7°C	500 h General Purpose Bomb ys Consentes
Volume %/°C	Height, it
Graness, Melis' Scale:	The state of the s
	Unaffected (Control of Control of
eung's Medulus:	Low Order
- 그 - 그	High Order
E', dynes/cm	
E, lb/inch²	1006-16 Streyal Fuspace Somb vs Concrete:
Cercity, gm/cc	
	Height, ft
empressive Strongth: lb/inch²	Friale
	Unaffected
oper Barsure:	Low Order
C mm Mercury	Migh Order

Baratol

Shaped Charge Effectiveness, THT = 100: 90 may 10E, M71 Projectile, Let WC-91: Gloss Cones Steel Cones Density, gm/cc Hole Volume Charge Wt, Ib Hole Depth **Total No. of Fragments:** Color: For TNT For Subject HE Principal Uses: Bomb filler 3 inch HE, M42A1 Projectile, Let KG-5: Density, gm/cc Charge Wt, Ib **Total No. of Fragments:** Method of Leading: Cast For TNT For Subject HE Leading D mily: gm/cc nent Velocity: ft/sec At 9 ft At 251/2 ft Density, gm/cc Method Dry Binst (Relative to TNT): Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Peak Pressure Impulse Exudation Energy Preparation: Air, Confin Impulse The appropriate weight of barium nitrate heated to about 90°C is added to molton TMT contained in a melting vessel equipped with an agitator. Continue mixing until uniform, and load by pouring at the lowest practical temperature. I<mark>nder Weter:</mark> Peak Pressure Impulse Energy Origin: Paratol, an explosive containing barium nitrate and TNT, the proportions varied to suit the required purposes, was developed during World War I. Impulse Energy

Baratol

References: 5

- (a) D. P. MacDougail, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (b) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSED Report No. 5746, 27 December 1945.
 - (c) Also see the following Picatinny Arsenal Technical Reports on Baratol:

 0
 3
 6
 8

 2010
 1783
 2226
 2138

 2160
 2233

(d) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

See footnote 1, page 10.

Baronal

Composition:	Molecular Weight:	111	
% Barium nitrate 50	Oxygen Belence: CO ₂ %	-24	
TNT 35	CO %	- 7	
Aluminum 15	Density: gm/cc	2.32	
	Melting Point: *C		
C/H Ratio	Freezing Point: *C		
mpact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 30	Builing Point: *C		
Sample Wt 20 mg	Refractive Index, no		
Picatinny Arsenal Apparatus, in. 12 Sample Wt, mg 22	ກະ		
	n ₂₀		
Friction Fondulum Test:	Vocuum Stability Test:	\	
Steel Shoe	cc/40 Hrs, at		
Fiber Shoe	90°C		
Rifle Bullet Impact Test: Trials	100°C		
%	120°C		
Explosions	135°C		
Partials	150°C		
Burned	200 Grew Bamb Sand Test:		
Unaffected	Sorad, ym	39.8	
Explosion Temperature: *C	Sonsitivity to initiation:		
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, gm		
l 5 Ignites 345	Mercury Fulntinate		
10	Lead Azide	0.20	
15	Tetryl	0.10	
20	Ballistic Mortar, % TNT: (a)	96	
	Treux! Test, % TNT:		
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method		
100°C Heat Test:	Condition		
% Loss, 1st 48 Hrs	Confined		
% Loss, 2nd 48 Hrs	Density, gm/cc		
Explosion in 100 Hrs	Brisance, % TNT		
Flammability Index:	Defonetion Rate: (b) Confinement	None	
1. A. A.	Condition	Cest	
Hygroscopicity: %	Charge Diameter, in.	1.0	
Valetility:	Density, gm/cc	2.32	
	Rate, meters/second	5450	

Beronal

Fragmentation Test: Shaped Charge Effectiveness, TNT = 100:						
90 mm HE, M71 Projectile, Let WC-91:	Glass Cones Steel Cones					
Density, gm/cc	Hole Volume					
Charge Wt, ib	Hole Depth					
Total No. of Fragments:	Color:					
For TNT	Com.					
For Subject, ME	Principal Uses: Bomb filler					
3 Inch HE, M42A1 Projectile, Let KC-5:						
Density, gm/cc						
Charge Wt, Ib						
Total No. of Fragments:	Method of Leading: Cast					
For TNT	William or Committee Control					
For Subject HE						
	Louding Density: gm/cc 232					
Fragment Valocity: ft/sec						
At 9 ft						
At 251/2 ft	Storage:					
Density, gm/cc	Mark and South					
	Method Dry					
Hest (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9					
Air:	Compatibility Group Group I					
Peak Pressure						
Impulse	Exudation					
Energy						
Air, Confined:	Preparation:					
Impulse	Procedure same as described under Baratol					
	except aluminum is added to the barium ni-					
Under Weter:	trate-TNT molton mixture under agitation					
Peak Pressure	until uniformity in comparison is obtained.					
impulse	Booster Sensitivity Test:					
Energy	(c)					
	Condition Cast Tetryl, gm 100					
Underground:	Wax, in. for 50% Detonation 0.86					
Dook Pressure						
Peak Pressure	Density, gm/cc 2.32					
Impulse						
	Density, gm/cc 2.32 Heat of:					
Impulse	Heat of:					
Impulse						

Beronel

References: 6

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosivis, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) G. ... Messerly, The Rate of Detonation of Various Explosive Composite, OSRD Report No. 1219, 22 February 1943.
- N. D. Burwits, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report Bo. 5611, 15 January 1946.
 - (e) D. P. MacDougall, <u>Methods of Physical Testing</u>, OSRD Report No. 803, 11 August 1942.
- (d) Arthur D. Little Report, Study of Pure Explosive Compounds, Part III, Correlation of Composition of Mixture with Performance, Contract No. DA-19-020-ORD-12, 1 May 1950.
- (e) S. J. Lowell, <u>Propagation of Detonation in Long and Marrow Columns of Explosives</u>, PATR No. 2136, February 1955.

⁶See footnote 1, page 10.

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Black Powder

Composition: 96	Melecular Weight:	84
Potessium nitreta 74.0	Gaygen Belence: CO ₂ % CO %	-55
Sulfur 10.4		
Charcoal 15.6	Density: g:::/cc Making Point: *C	Variable
C/H Ratio	Freezing Point: *C	
Bureau of Mines Apparatus, cm 32 Sample Wt 20 mg Picatinny Ansenal Apparatus, in. 16 Sample Wt, mg 16	Beiling Point: *C Refrective Index, nonnnnnnnnnnnnnnnnnnnnnnnnnnnnnnnnnnn	
Sompic Wi, mg	n _m	
Frience Pendelum Test: Steel Side Snaps Fiber Show Unaffected	Vecuum Stubility Test: cc/40 Hrs, at 90°C 100°C	0.5
Riffle Bullet Impact Test: Trials Kaplasians	120°C 135°C	0.5
Portiols Burned Unaffected	200 Grem Bomb Sead Test: Sand, gm	8
Explosion Temperature: °C Seconds, 0.1 (no cap used) 510 i 490 5 Ignites 427 i0 356	Sensitivity to Initiation: Minimum Detonating Charge, Mercury Fulminate Lind Azide Tetryl Sensitive to igniting fue Bellistic Morter, % TNT:	ses
20	Trougi Test, % TNT: (a)	10
75°C International Heat Test: % Loss in 48 Hrs 0.31 160°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc	
Exclosion in 100 Hrs	Brisance, % TNT	
Flammebility Index:	Detonation Rate: Confinement Condition	
Hygrescapicity: % 25°C, 75% RH 0.75 25°C, 90% RH 1.91 30°C, 90% RH 2.51	Charge Diameter, in. Density, gm/cc	1.6
Volatility:	Density, grit/cc	2.0

Black Powder

regmentation Test:		Sheped Charge Effectiveness, TNT = 100:			
90 mm HE, M71 Projectile, Let WC-)1:	Glass Cones Stee! Cones			
Density, gm/cc		Hole Volume			
Charge Wt, Ib		Hole Depth			
Total No. of Fragments:		Color: Black			
For TNT	* •	Com. Dieck			
For Subject HE		Principal Uses: 1. Igniter powder			
3 inch HE, M42A1 Projectile, Let KC	.	2. Time rings (fuzes)			
Density, gm/cc					
Charge Wt, Ib					
Cicigo VVI, io					
Total No. of Fragments:		Method of Looding: 1. Loose (granulated)			
For TNT		2. Pressed			
For Subject HE		Legitor Density: cm/cr psi x 10 ³			
regment Velocity: ft/sec		25 50 60 65 70 75 1.74 1.84 1.86 1.87 1.88 1.89			
At 9 ft At 251/2 ft		Storage:			
Density, gm/cc		Method Dry			
liest (Relative to TNT):		Hazard Class (Quantity-Distance) Class 9			
Aire		Compatibility Group Group 0			
Peak Pressure					
Impulse		Exudation None			
Energy		:			
		100°C Vacuum Stability Test,			
Air, Cenfined: Impulse		cc gas/40 hrs:			
··· qualita		Initial Value 0.5 After 2 hours at 65°C 0.86			
Under Water:		After 2 hours at 65°C, 75% RH 1.46			
Peak Pressure		Sensitivity to Electrostatic			
Impulse		Discharge, Joules: (b)			
Energy		Unconfined >12.5			
Underground:		Confined 0.8			
Peak Pressure		Compatibility with Metals:			
impulse		Dry - Compatible with all metals when			
Energy		moisture content is less than 0.20			
Initiating Efficiency:		Wet - Attacks all common metals except steinless steel.			
Grams Required to Initiate		Heat of:			
Igniter Comp K+31	2.0				
Igniter Comp K-29	2.3	Explosion, ca!/qm 684 Gas Volume, cc/gm 271			

Preparation:

willow or alder charcoal, flour of sulphur and 2-3% of water are placed in a tumbling barrel and mixed for a short period (about 1/2 hour). The mixture is transferred to a "wheel mill" and crystalline potassium nitrate containing 3-4% moisture is added and the mixture is in orporated for several hours. During the incorporation period the mixture is kept damp (2-3% moisture) by adding water at intervals. The mill cake is then pressed at 5000 psi between aluminum plates. The pressed cakes are broken up between rubber or wood rolls. The material is screened and the various particle sizes are separated as desired. The screened material is then transferred to convast rays and dried in hot air owens at 60°C. If it is desired to glaze the black powder, the material before drying is polished by rotation in a tumbling barrel to give it a smooth surface. It is next screened to remove the dust. The smooth particles are then placed in a wooden barrel and rotated with graphite. The material is again screened to remove the excess graphite, and dried. Material finer than \$40 U. S. Sieve is not graphited.

WARNING

The batches of black powder must be of sufficient size to cover the bed of the "wheel mill." If the wheels run off on the bare bed, explosions usually result.

Origin:

The exact date of the discovery of black powder is unknown. Historians attribute its discovery to the Chinese, Hindus or Arabs. The Greeks used it during the 7th Century. Marcus Graecus in the 9th Century and Roger Bacon in the 13th Century described compositions similar to the present powder. Beginning with the 16th Century, the composition of black powder containing potassium nitrate, charcoal and sulfur has remained unchanged with respect to the proportionality (75/15/10) of the ingredients.

Destruction by Chemical Decomposition:

Black powder can be desensitized by leaching with water to dissolve the potassium nitrate. The washings must be disposed of separately because the residue of sulfur and charcoal is combustible but not explosive.

References: 7

- (a) Fh. Naoum, Nitroglycerine and Nitroglycerine Explosives, Baltimore, 1928.
- (b) F. W. Brown, D. H. Kusier and F. C. Gibson, Sensitivity of Emplosives to Initiation by Electrostatic Discharges, U. S. Department of the Interior, Bureau of Mines RI 3852, 1946.
 - (c) Also see the following Picatinny Arsenal Technical Reports on Black Powder:

See footnote 1, page 10.

Black Powder AMCP 706-177										
<u>o</u>	1	2	3	4	٤	<u>6</u>	I	<u>8</u>	2	
250 710 850 1010 1450	\$1 471 661 901 1111 1241 1451 1541 1711 1951 2051	222 \$72 \$72 \$72 \$92 582 762 872 1022 1712 1802 1912	163 363 453 843 1043 1153 1243 1393 1493 1643 1813 1843 1973	354 554 554 554 554 654 664 774 844 1154 1244 1504	65 415 545 605 1145 1275 1815 1885 1905 1915	56 176 356 686 746 1256 1316 1536 1576 1586 1946	347 407 437 547 757 847 1097 1737 1797 1807 1827	188 318 428 558 598 608 618 698 898 1068 1388 1528 1778 1838 1838	379 819 839 849 859 1259 1309 1339 1349 1589 1739 1869	

AMCP 706-177

1,2,4-Butanetriol Trinitrate (BITN) Liquid

Composition:		Moleculer Weight: (C4H7N309)	241			
c 19.9		Oxygen Belence:				
H ₂ C-ONO ₂	!	CO. % CO %	-17			
и 2.9 г.		CO %	10			
N 17.5 / HC-ONO		Density: gm/cc Liquid	1.52			
0 59.7		Melting Point: °C				
H ₂ Č-ONO ₂ C/H Ratio 0.13		Freezing Point: °C				
impact Sanditivity, 2 Kg Wt:	FO	Bailing Point: °C				
Bureau of Mines Apparatus, cm Sample Wt 20 mg	58	Refrective Index, 120	1.4736			
Picatinny Arsenal Apparatus, in.	≰l	nº	114130			
Sample Wt, mg	_	n D				
Friction Pendulum Test:		Vocuum Stability Test:				
Steel Shoe		cc/40 Hrs, at				
Fiber Shoe		90°C				
Rifle Bullet Impa : Test: Trials		100°C	2.33			
		120°C				
% Explosions		135°C				
Partials		150 ⁻ C				
Burnzd	•	200 Gram Romb Send Test:				
Unaffected		Sand, gm	48.6			
Explosion Tomperature: "C		Sensitivity to Initiation:				
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gr	1			
1	•	Mercury Fulminate				
5 Decomposes 23	D	Leod Azide	0.20			
10		Tetry!	0.10			
15 20		Bellistic Morter, % TNT:				
		Treezi Test, % TNT:				
75°C International Neat Tost: % Loss in 48 Hrs		Plate Dent Test:				
		Method Condition				
100 C Heet Test:		Condition				
% Loss, 1st 48 Hrs	1.5					
% Loss, 2nd 48 rins	1.2	Density, gm/cc Brisonce, % TNT				
Explosion in 100 Hrs	None					
Flemmebility Index:		Detenation Rate:				
The state of the s		Confinement				
Hygroscopicity: % (a)		Condition				
100°F, 95% RH, 24 hrs	0.14	Charge Diameter, in				
Veletility:		Density, gm/cc				
60°C, mg/cm²/hr	46	Rate, meters/second				

1,2,4-Butanetriol Trinitrate (BTIN) Light

regeneration Test:	Shaped Charge Effectiveness, TNT % 100:
90 cnm HE, M71 Projectile, Let WC-91:	Glass Cones Steel Cones
Density, gm/cc	Hale Valume
Charge Wt, Ib	Hole Depth
Total 14s. of Fragments:	Color: Yellow oul
For TNT	Color: Yellow oil
For Subject ME	Principal Uses: Explosive plasticizer for
3 inch HE, M42A1 Projectile, Let K6.5	nitrocell:lose
Density, gm/cc	}
Charge Wt, Ib	
Total No. of Fragments: For TNT	Method of Louding:
For Subject HE	
	Looding Density: gm/cc 1.52
agmont Velocity: ft/sec At 9 ft At 25½ ft	Storage:
Density, gm/cc	/Aethod
et (Relative to TNT):	Hazard Class (Quantity-Distance)
Air:	Compatibility Group
Peak Pressure	
†mpulse	Exudation
Energy	<u> </u>
Air, Confined:	Solubliity is Water, (a) gm/100 gm, et:
Under Weter:	20 0 0.04 60°0 0.15
Peak Pressure	Solubilit of Water in. (8)
Impulse	5m/100 gm: 0.04
Energy	Solubility, gm/100 gm.
Underground:	8 25°C, 1c:
Peak Pressure	Alcohol
impulse Energy	2:1 Ether:Alcohol « Acatone »
les . of: (E)	Wis voite, reprigations: (a)
Combistion rel/m (1)	
Exp Deion, col/m. 16.7	10 to 10 10 10 10 10 10 10 10 10 10 10 10 10
Gas Volume, comma	1

AMCP 706-177

1,2,4-Butanctriol Trinitrate (BTTK) Liquid

Preparation (Laboratory Procedure):

To a cooled mixture of 73.8 gm of 100% nitric acid, 46.2 gms of 106.2% sulfuric acid and 60.0 gm of 96.1% sulfuric acid, 30 gms of the original (or redistilled) 1,2,4-butanetriol was added dropwise with agitation for a period of thirty minutes. The temperature of the reaction mixture was kept at 0°-5°C. When the agitation was completed stirring was continued for one and one-half hours. The mixture was powed into ice water, and the resulting oil suspension was extracted with three 100 milliliter portions of other. The combined other extracts were washed with water, then with a 5% sedium bicarbonate solution and finally with water. The neutralised extract was dried with anhydrous calcium chloride and then the other was weaponated. The yellow oil was dried in a vacuum desicostor over anhydrous calcium chloride until the material was brought to constant weight.

Origin:

1,2,4-butanetriel was first synthesized by Wagner and Ginsberg in 1894 by oxidizing allyl carbinol with potassium perconganate under mild conditions (Ber 27, 2437). Recently the U. S. Rubber Laboratory, under the direction of P. Tawney, devised a new synthesis carried out with allyl acetate and formaldehyde to give 1,2,4-butane triacetate which was readily hydrolysed to butanetriol (U. S. Rubber Company Guarterly Report, May 1948). Working with pure 1,2,4-butanetriol prepared by an improved technique of the Wagner method, the U. S. Ruval Imboratory in 1948 nitrated the butanetriol on a laboratory and a pilot plant scale (Reference a).

Ruferences: 3

- (a) J. A. Gallaghan, F. Macri, J. Bednarik, and F. McCollum, The Synthesis of 1,2,4-Butanetriol and the Evaluation of Its Trinitrate, U. S. Naval Powder Pactory Technical Report No. 19, 10 September 1948.
- (b) Also see the following Picatinny Arsens: Technical Reports on Butanetriol Trinitrate: 1755 and 2786.

⁸See rootnote 1, page 10.

Composition:		Melecular Weight:		227
		Oxygen Belence:		
RDX 91		CO. % CO %		-48 -23
Wax 9				
		Density: gm/cc 12,0	00 pai	1.65
		Melting Point: *C.		
C/H Ratio		Freezing Point: 'C		
mpact Sanaktivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	100+	Beiling Point: *C		
Sample Wt 20 mg		Refrective Index, 1120		
Picatinny Arsenal Apparatus, in. Sample Wt, mg	16 17	n _{2s}		
¥ -	-,	n <mark>⊊</mark>		
riction Pondulum Test:		Vacrum Stability Test:		***************************************
Steel Shoe Unaffe		cc/40 Hrs, at		
Fiber Shoe Unaffe	eted	90°C		
Rifts Bullet Impact Test: Trials		120°C		0.3
- %		135°C		0.6
Explosions 0		150°C		
Portials 0 Burned 0				
Unaffected 100		! 200 Gram Bemb Sand Test Sand, gm	E) E	
				51.5
Explosion Temperature: "C Seconds, 0.1 (no cap used)		Sensitivity to Initiation: Minimum Detenating C	horne om	
1		Mercury Fulminate	ande' Au	0.22*
5 Decomposes 250		Lead Azide		0.25*
10		* Alternative initiat	ing here	
15		Bellistic Morter, % TNT:		
20		Troug! Test, % TNT:	(a)	13)
S'C International Heat Test:		Plate Dont Tut:	(b)	
% Loss in 48 Hrs		Method	B	В
00°C Heat Tast:		Condition	Pressed	Pressed
% Loss, 1st 48 Hrs	0.15	1	No	No
% Loss, 2nd 48 Hrs	0.15		1.61	1.20
Explosion in 100 Hrs	None	Brisance, % TNT	126 	75
amachility Indon.	100		(c)	
lemmebility Index:	195	Confinement		None
lygrescopicity: % 30°C, 90% RH	0.0	Condition		Pressed
		Charge Diameter, in. Density, gm/cc		1.0
electificy: 50°C, 15 days	7.03	Density, girit cc		1.59

Fregmentation Test:		Shapes Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile, Lot	WC-91:	Glass Cones Steel Cones
Density, gm/cc	1.62	Hole Volume
Charge Wt, Ib	2.102	Hole Depth
Total No. of Fragments:		Color: White-buff
For TNT	703	Color: White-buff
For Sucject HE	1138	Principal Uses: HE, SAP, AP projectiles;
3 inch HE, M42A1 Projectile, Lo	KC-5:	Shaped Charges
Density, gm/cc	1.64	
Charge Wt, Ib	0.861	
Total No. of Fragments:		Method of Looding: Pressed
For YNT	514	Treased
For Subject HE	710	Leading Density: om/cc psi x 10 ³
Engage and Valuation to the same		3 12
Fragment Valocity: ft/sec At 9 ft At 25½ ft	2800 2530	1.47 1.65
Density, gm/cc	1.61	
bersity, gilly cc		Method Dry
Blast (Relative to TNT):		liazard Class (Quantity-Distance) Class 9
Air:		Compatibility Group Group I
Peak Pressure		Endation 3 not exude at 65°C when waxe.
Inipulse		multing sharply at or above 75°C are used.
Energy		Preparation:
Air, Confined:		
Impulse		A water slurry of RDX is heated to 100°C with agitation. Wax and a wetting agent are added and the mixture, under agitation, is
Under Water:		cooled below the melting point of the wax.
Peak Pressure		The wax coated RDX is collected on a filter
Impulse		and air dried at 75°C.
Energy		Effect of Temperature on Fate of Detonation: (e)
Undergreend:		16 hrs at, °C -54 21
Peak Pressure		Density, gm/cc 1.51 1.51 Rate, m/sec 7600 7620
Impulse Energy		Booster Sensitivity Test: (d)
Energy		
		Condition Pressed Tetryl, gm 100
		Wax, in. for 90% Detonation 1.70
		Density, gm/cc 1.62
		Heat of:
		Oumbustion, cal/gm 1210

Compatibility with Metals:

Dry - Aluminum, stainless steel, mild steel, mild steel coated with acid-proof black paint and mild steel plated with nickel or zinc are unaffected. Copper, magnesium, magnesium-aluminum alloy, brass and mild steel plated with cadmium or copper are slightly affected.

Wet - Stainless steel is unaffected. Copper, aluminum, magnesium, brass, mild steel, mild steel coated with acid-proof black paint and mild steel plated with copper, cadmium, nickel or zinc are slightly affected.

Origin:

Developed by the British during World War II as RDX and beeswax. Subsequent changes in the United States replaced beeswax with synthetic wares, changed the granulation of RDX and improved the method of manufacture.

Destruction by Chemical Decomposition:

RDX Composition A-3 (RDX/wax, 91/9) is decomposed by adding it slowly to 25 times its weight of boiling 5% sodium hydroxide. Boiling of the solution is continued for one-half hour.

References: 9

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
 - (b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (c) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.
- M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.
- (d) L. C. Smith and S. R. Valton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, dated 15 June 1949.
- (e) W. F. McGarry and T. W. Stevens, Detonation Ret 3 of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383. November 1956.
 - (f) Also see the following Picatinny Arsenal Technical Reports on RDX Composition A-3:

<u>o</u>	<u>1</u>	2	3	4	2	<u>6</u>	7	8	9
1380 1910	1451 1761	1492 2112	1493	1424 1614 1634 2154	1325 1585 1595 1715 1835 2235	1556 19 3 6	1637 1737 1797	1336 1388 1723 18 3 8	1639 2179

⁹See footnote 1, page 10.

Composition B

Semposition: 96		Melecular Weight:	224
RDX 60		Oxygen Belence: CO ₂ %	-43
TNT 40		CO %	10
		Density: gm/cc Cast	1.65
Wax, added 1		Melting Point: "C (1)	78-80
C/H Ratio		Freezing Point: *C	
npact Sanakivity, 2 Kg Wit:	75	Soiling Point: 'C	
Bureou of Mines Apparatus, cm Somple Wt 20 mg	12	Refrective Index, no	
Picatinury Arsenal Apparatus, in.	14	n <u>R</u>	
Sample Wt, mg	19	n _s	
riction Pendulum Test:		Vocuum Stability Test:	
Steel Shoe Unaffect		cc/40 Hrs, at	
Fiber Shoe Unaffect	ted	90°C	
Liffe Bullet Impact Test: Trials		160.C	0.7
•		120°C	0.9
Explosions %		135°C	
Partials 13		150°C	11+
Burned 4		200 Grem Somb Sond Test:	
Unaffected 80		Sand, gm	54.0
uplation Temperature: 'C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used) 526		Minimum Detonating Charge	
1 368		Mercury Fulminate	0.22*
5 Decomposes 278		Lead Azide	0.20*
10 255		Tetryl * Alternative initiating	charges
15 > 25∪ 20 > 250		Bellistic Morter, % TNT: (a)	
		Trouzi Test, % 1NT: (b)) 130
5°C International Hout Tost: % Loss in 48 Hrs		Plate Deat Test: (c)	•
		Method	B 60-44
90°G Heat Test:		Condition	Cast
% Loss, 1st 48 Hrs	0.2	Confined	No
% Loss, 2nd 48 Hrs	0.2	Density, gm/cc	1.71
Explosion in 100 Hrs	None	Brisance, % TNT	132
namebility Index:	177	Detenation Rate: Confinement	None
	- 1.	Condition	None
tygrescopicity: % 30°C, 90% RH	0.02		1.0
, 2, 10 30 0, you ldi		Charge Diameter, in.	1.68
/eletility:		Density, gm/cc	
		Rate, meters/second	7540

Composition B

Beater Schellivity Test. Condition	(d) Cast	Decomposition Equation: Oxygen, atoms/sec (Z/sec)	•	
Tetryl, gm	100	Heat, kilocolorie/mok	•	
Wax, in. for 50% Detonation	1.40	(ΔH, kcal/mol)		
Wax, gm	_	Temperature Range, ⁴	C	
Density, gm/cc	1.69	Phase		
Heat of: Combustion, col/gm	(e) 2790	Armor Plate Impact Test	:	(e)
Explosion, cal/gm	1240	40 mm Morter Project	110a	
Gas Volume, cc/gm		50% Inert, Velocity		209
Formation, cal/gm		Aluminum Sineness		- -
Fusion, cal/gm (1)	ૄ. 0			
		500-lb General Purpos	e Bembe:	
Specific Heat: cal/gm/*C (2)		Plate Thickness, inc	ches	
			Trials	% Inert
-75 0.23 5 75	0.376	1	4	100
0 0.220 85 25 0.25 90	0.354 0.341	11/4	6	50
50 0.305 100	0.312	11/2	2	0
	-	134	0	
Thermal Conductivity: cxil/sec/cm/*C		Bomb Drop Test: T7, 2000-lb Somi-Arm	nor-Piercing (lemb vs Cencro'e:
Coefficient of Expension:		Max Safe Drop, ft		
Linear, %/*C		500-lb General Purpo	se Bomb vs (No Seal	Concrete: Seal
Volume, %/°C		Height, ft	4000	400
		Trials	65	3>)
Hardness, Mohs' Scale:		Unafrected	5 8	3 6
		Low Order	2	2
Young's Medulus:		High Order	5	1
E', dynes/cm²				_
E, Ib/inch²		1000-lb General Purp	ose Bomb vs (Concreto:
Density, gm/cc				
		— Height, ft		
Compressive Strongth: lb/inch ² (b)	1610-2580	Trials		
Density, gm/cc	1.68	Unaffected		
Vapor Pressure:		Low (1er		
*C mm Mercury		High Order		
			· ——	

Composition B

Fragmentation Test:		Shaped Charge Effectiveness, TNT = 100:	
00 mm ME M71 0-1-41-4	WC 01.	(g) (h)	
90 mm HE, M71 Projectile, Lat		Glass Cones Steel Conec	
Density, gm/cc	1.65	Hole Volume 178 162	
Charge Wt, Ib	2.187	Hole Depth 125 148	
Total No. of Fragments:		Color: Yellow-brown	
For TNT	703	ieilow-brown	
For Subject HE	998	Principal Uses: Fragmentation bombs,	
3 inch HE, M42A1 Projectile, Lot	KC-5:	projectiles, grenade	s, shaped
Density, gm/cc	1.67	charges	
Charge Wt, Ib	0.662		
Total No. of Fregments;		Mathed of Lordina	
For TNT	514	Method of Loading: (**)	i
For Subject HE	701	Loading Density: gm/cc 1.6	٦
Fragment Velocity: ft/sec			-
At 9 ft	2940		
At 25½ ft	2680	Storege:	
Density, gm/cc	1.68	Method Dr	
		·	ry
liest (Relative to TNT):	(r)	Hazard Class (Quantity-Distance) C1	lass 9
Air:		Compatibility Group G1	roup I
Peak Pressure	110		• -
Impulse	110	Exudation Very slight when stored	at 71°C
Energy	116		
Air, Confined:		Origin:	
Impulse	7 5	RDX Composition B was developed b	ur +h-
		British between World War I and Wor	
Under Weter:		It was standardized by the United S	
Peak Pressure	110	early in World War II.	
Impulse	10 8	Effect of Temperature on	
Energy	121	Rate of Detonation:	(i)
Underground:		16 hrs at, °C -54	24
Peak Pressure	104	Density, gm/cc 1.69	1.69
Impulse	97	Rate, m/sec 7720	7660
Energy		Bulk Modulus at Room	(;)
Crater radius cubed	107	Tempersture (25°-30°C):	
	 ,	% Wex in Comp B 1 2	3
		Dynes/cm ² x 10 ⁻¹⁰ 5.10 3.50	2.34
		Density, nm/cc 1.72 1.70	1.47
		Viscosity, poises:	3 1
		Temp, 6300 9500	3.1 2.7

Compatibility with Metals:

Dry - Magnesium, aluminum, magnesium-aluminum alloy, mild steel, stainless steel, mild steel coated with acid-proof black paint and mild steel plated with zinc or nickel are unaffected. Copper, brass and mild steel plated with copper or cadmium are slightly affected.

Wet - Aluminum and stainless steel are unaffected. Copper, brass, mild steel, mild steel coated with acid-proof black paint and mild steel plated with cadmius, copper, nickel or zinc are slightly affected. Magnesium and magnesium-aluminum alloy are more heavily affected.

Preparation:

Water wet RDX is added slowly with stirring to molten Two melted in a steam-jacketed kettle at a temperature of 100°C. Some water is poured off and heating and stirring are continued until all moisture is evaporated. Wax is then added and when thoroughly mixed, the composition is cooled to a satisfactory pouring temperature. It is east directly into ammunition components or in the form of chips when Composition B is to be stored.

Destruction by Chemical Decomposition:

RDX Composition B is decomposed in 12 parts by weight of technical grade acetone heated to 45°C. While this is stirred vigorously, there is added 12 parts of a solution, heated to 70°C, of 1 part sodium sulfide (Na₂S'9H₂O) in 4 parts water. The sulfide solution is added slowly so that the temperature of the acetone solution does not rise above 60°C. After addition complete, stirring is continued for one-half hour.

References: 10

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensiti..ty Tests; Performance Tests, OuRD Report No. 5746, 27 December 1945.
- (b) Philip C. Keenan and Dorothy Pipes, Table of Military Righ Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
 - (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) Smmittee of Divisions 2 and 8, NDRC, Report on HF' and Tritonal, CTRD Report No. 5406, 31 July 1945.
- (f) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W572-ORD-5723.
- (h) Eastern Laboratory du Pont, <u>Investigation of Cavity Fffect</u>, Final Report, E Lab du Pont, Contract W-672-ORD-5723, 18 September 1943.
- (i) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November, 1956.

¹⁰See footnote 1, page 10.

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Composition B

(j) W. S. Crewer, Bulk Compressibility Data on Several High Explosives, NAVORD Report No. 4380, 15 September 1955.

(k) Also see the following Picatinny Arsenal Technical Reports on RDX Composition B:

<u>o</u> .	1	2	3	4	5	<u>6</u>	I	<u>8</u>	2
1360 1530 2100 2160 2190	1211 1451 2131 2151	1402 1482 1592	1313 1433 1803 1983 2053 2063 2103 2233	1424 1944 2004 2104	1325 1435 1585 1595 1865 1885 2055 2125	1466 1476 1556 1756 1956 2257	1207 1437 1457 1737 1797 2007 2147	1338 1368 1438 1458 1688 1728 1828	1339 1379 1469 1819 7019
			E233		2155 2175 2235			1978 2008 2138	

(1) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Fusion Explosives, PATR No. 2504, January 1959.

Composition B, Desensitized

Composition:	<u>I*</u>	11**	Molecular Weight:	<u>]*</u> e Cyclouite	II++ See Comp R
RDX	60 40	55.2 40.0	Oxygen Balence:		
TNT	4 0	40.0		e Cyclonite	See Comp B
Wax, added, (Stanolind or Aristowax, 1650/ 1700F)	5		1	e Cyclonite	See Comp B
Vinylseel (MA28-14), edded	2		Density: gin/cc Cast	1.65	1.65
Vistanex (Bl20) Albecer Wax		1.2 3.6	Melting Point: *C	·	
C/H Ratio			Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	<u>I*</u> 95	<u> </u>	Boiling Point: *C		
Sample Wt 20 mg	••		Refractive Index, no		
Picatinny Arsenal Apparatus, in.	14	13	n _o		
Sample Wt, mg	17	16	=		
			n _m		
Friction Pendulum Test: Stud Shoe Unaffect	-e3		Vacuum Stability Test:	<u>I*</u>	11**
			cc/40 Hrs, at 90°C		
Fiber Shoe Unaffect	æu		- 100°C		
Rifle Bullet Impect Test: Trials			· ·	0.99	0.92
%	I*	11**	120°C	0.33	0.72
Explosions ~~	0	0	135°C	• • •	
Partials	0	0	150°C	11+	11+
Burned	5	0	200 Grem Bomb Sond Test:	<u>I*</u>	II**
Unoffected	95	100	Sand, gm	52.7	55.0
Explosion Te preture: °C	<u>I*</u>	II**	Sensitivity to Initiation:	<u>I*</u>	II**
Seconds, 0.1 (no cap used)			Minimum Detonating Ch	iorge, gm	
l 5 Decomposes 2	260	070	Mercury Fulminate		
•	200	270	Lead Azide	0.22	0.26
10 15			Tetryl		
20			Bellistic Morter, % TNT:		
			Trouzi Test, % TNT:		
75°C International Heat Test: % Loss in 48 Hrs			Plata Dent Test: Method		· · · · · ·
10. C Heet Test:	<u>I*</u>	II**	Condition		
% Loss, 1st 48 Hrs	0.05	0.12	Confined		
% Loss, 2nd 48 Hrs	0.19	0.18	Density, gm/cc		
Explosion in 100 Hrs	None	None	Brisance, % TNT		
Flammability Index:	·		- Detonation Rate: Confinement		
			1		
Hygrescapicity: %			Condition		
30°с, 90% RH	0.00	0.00	Charge Diameter, in.		
Voistifity:	Nil	Nil.	Density, gm/cc		
·	74T T	44.4	Rate, meters/second		

^{*}Desensitized Comp P, designated I, uses emplaified wax. **Desens'tized Comp B, designated II, uses costed RDX.

Composition B, Desensitized

Fragmentation Test:			Shaped Chan	pe Effectiven	ess, TNT = 10	10:
90 mm HE, M71 Projectile,	Let WC-91:			Gloss on	nes Steel C	ones
Density, gm/cc			Hole Volum	me		
Charge Wt, ib			Hole Depti	י		
Total No. of Fragments:			Color:		Yellow-t	rour
Cor TNT			Color.		16110#-0	/I Own
For Subject HE			Principal Use		Bombs	
3 inch HE, M42A1 Projectile	, Lot_KC-5:		1			
Density, gm/cc	1.65	11** 1.65				
Charge Wt, Ib	0.87	0.86				
Total No. of Fragments:			Material of Le		Cast	
For TNT	514	5₌՝	Method of Le	odaing;	Cast	
For Subject HE	609	659				
			Louding Dent	ilty: gm/cc	1.65	
Fragment Velocity: ft/sec At 9 ft					······································	
.^+ 25⅓ ft			Storage:			
Density, gm/cc			Method			
			Memod		i	ry
Blast (Relative to TNT):			Hazard Cl	ass (Quantity	-Distance) (class 9
Air:			Compatibil	lity Group	G	roup I
Peak Pressure			į			
Impulse			Exudation			
Energy						
Air, Confined:			Viscosity,	poises:	<u>I*</u>	II**
Impulse			Тетр, 83	3°C	3.5	3.1
			95	60 0	3.5 2.6	ž.7
Under Water: Peak Pressure			Reference	:•		
Impulse			References	· <u>·</u>		
Energy						nny Arsenel
			Technical Desensitiz		RDX Compus	ition B,
Underground:				•		,
Peak Pressure			1	3	<u>5</u>	<u>6</u>
			21)1	1313	1435	1750
impulse						
Impulse Energy				2053	1865	
_ '	dignated .	uses				
Energy						

Compression C

Composition:	Kelecular Weight:
RDX 88.3	Oxygen Referee: CO ₂ %
Platicizer, non-	CO %
explosive 11.7*	Density: grn/cc
*Monexplosive oily plasticizer containing 0.6% lecithin.	
C/H Ratio	Freezing Point: 'C
Impact Sentitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+	Belling Petat: *C
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Refrective Index, no
Friction Pendulum Test:	
Steel Since	Vecuum Stribi'ity Test: cc/40 Hrs, at
Fiber Shoe	90°C
	100°C 0.3
Riffe Bullet Impiecr Test: Tricis	120°C 0.7
5t-sim-	135°C
Explains 0 Partials 0	150°C
Partials 0 Burned 0	
Unaffected 100	200 Gram Bomb Sand Test:
Onorrected 100	Sand, gin 46.5
Explorion Temperature: *C	Sensitivity to Initiation:
Sizconds, 0.1 (no cop used)	Minimum Detonating Charge, gm
5 72222222 295	Mercury Fulminate
5 Decomposes 285	Leod Azide 0.25
10	Tetryl 0.11
15 20	Bellistic Morter, % TNT: (a) 120
	Treuzi Test, % TNS:
75°C International Heat Test:	Plate Dont Test:
% Loss in 48 Hrs	Method A
180°C Heat Test:	Condition Hand Tamped
96 Loss, 1st 48 Hrs 0.04	Confined Yes
% Loss, 2nd 48 Hrs 0.00	Density. gm/cc 1.58
	Brisonco, % TNT 112
Explosion in 100 Hrs None	· · · · · · · · · · · · · · · · · · ·
Flummebility Index:	Detenation Rete:
	Confinement
Hygrescopicity: % 30°C, 95% RH 0.25	Condition
	Charge Diameter, in.
Valuellity: 25°C, 5 days 0.00	Density, gm/cc

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Corposition C

Fregmentellen Test:	Shaped Charge Effectiveness, THT = 100: (£) (g)
90 mm HE, M71 Projectile, Let WC-91; Density, gm/cc	Glass Cones Steel Cones Hole Valume 113 114
Charge Wt, Ib Tatel No. of Fragmants:	Hole Depth 101 11
For ThiT For Subject HE	Colors White
3 inch ME, M42A1 Projectific, Lnt KG-5: Deneity, gm/cc Charge Wt, Ib	Plastic demolition explosive
Total No. of Fragments: For TNT	Mathed of Leedings Hand tamped
For Subject HE	Leeding Density: gm/cc 1.49
Programs Velocity: ft/sec At 9 ft At 25½ ft	Shureges
Deneity, gm/cz	Method Dry
Steat (Relative to TNT):	Hazard Class (Quantity-Distance) CLass 9
Airs Peak Pressure Impulse Energy	Composibility Group Group I Exudation Exudes above 40°C
Air, Confined: Impulse Under Water:	Plasticity: Below O°C Brittle (0°C) 0-40°C Plastic Above 40°C Endes (40°C)
Peak Pressure Impulse	Above 40°C Emides (40°C) Paferences:
Energy Underground: Peak Pressure Impulse Energy	See references for Composition C-4.

Compeablen:		Melecular Weigl.	
RDX 78.7		Oxygen Belence:	
THT 5.0 DMT 12.0		CO ₂ % CO %	
12.0 1877 2.7		CO 70	
NC 0.6 Solvent 1.0		Density: gm/cc	
SOLVERC 1.0		Molting Point: *C	
C/H Rotio	_	Freezing Point: *C	
Impact Sensitivity, 2 Kg Wt:		Builing Point: *C	
Bureau of Mines Apparatus, cm 90 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg		Refrective Index, nº	
Fristian Pandulum Test:		Vocuum Stability Test:	
Steel Shae Fiber Shae		cc/40 Hrs, at	
FINAL SUID		90°C 2.0	
Riffe Bullet Impact Test: Triols		4.0	
%		120°C 9.0	
Explosions 0		135°C	
Partials 20		130 C	
Burned 0		200 Gram Bamb Sand Test:	
Unaffected 80		Sand, gm 47.5	
Explosion Temperature: 'C		Sensitivity to Initiation:	
Secreds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5 Decomposes 285		Lead Azide 0.25	
10		Tetryl 0.10	
15 20		Bellistic Morter, % TNT: (a) 126	
		Trough Toot, % TMT:	
75°C International Heat Test: % Loss in 48 Hrs		Plate Dest Test: (c) Method B	
100°C Heat Test:		Condition Hand tamped	
% Loss, 1st 48 Hrs	1.8	Confined No	
% Loss, 2nd 48 Hrs	1.4	Density, gm/cc 1.52	
Explosion in 100 Hrs	None	Brisance, % TNT 111	
		Outrocation Retay (A)	
Flommobility Index:	178	Detenation Rate: (d) Confinement None	
-		Confinement None Condition Hand tamped	
Mygraecopicity: % 30°C, 95% RH	0.55	Charge Chameter, in. 2.0	
		Density, gm/kc 1.57	
Veletility: 25°C, 5 days	0.00	1.7/	

regularitation Test:	Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, lb	Glass Cones Steel Canes Hale Volume Hale Depth
Total No. of Fragments: For TNT	Color: White
For Subject HE	Principal Uses: Plastic demolition explosi
3 Inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc	
Charge Wt, Ib	
Total No. of Fragments: For TNT For Subject HE	Method of Leading: Hand tamped
FOR Subject FIE	Locding Density: gm/cc 1.57
regment Velocity: ft/sec At 9 ft At 25½ ft	Storage:
Density, gm/cc	Method Dry
lest (Relative to TNT)	Hozard Class (Quantity-Distance) Class 9
Air: Peak Pressure Impulse Energy	Compotibility Group Group I Exudation Volatilizes above 52°C
Air, Confined: Impulse	Plasticity: Below O°C Plastic (-30°C) 0-40°C Plastic
Under Weter: Peak Pressure	above 40°C Hard (52°C)*
hpulse Vnergy	*Due to volitalization of plasticizer. References:
Undchreund: Peak Pressure	See references for Composition C-4.
Impulso Energy	:
d*	
	1

Compacition:	Molocutar Weight:
%	Oxyg. n Colonse:
RDX 77	CO. A
Tetryl 3	co %
INT 10	
NET 5	Density: gm/cc
¥C 1	Meltine Point: "C
C/H Ratio	Freezing Point: *C
Impact Seasitivity, 2 Kg Wt:	Bailing Paint: *C
Bureau of Mines Apparatus, cm 100+	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 14	Refrective Index, no
Picatinny Arsenal Apparatus, in. 14 Sample Wt, mg 33	n <mark>o</mark>
33	n _{ac}
Friction Pendulum Test:	Vacuum Stability Test:
Steel Shoe Unaffected	cc/40 Hrs, at
Fiber Shoe Unaffected	90°C
Ave. Bullet Inc a Cont Tit.	100°C 1.21
Rifle Bullet Impact Test: Trials	120°C . 11+
% Fundament	135%
Explosions 0	150°C
Partials 40	
Burned 0	2f 7 Grem Bomb Sand Test:
Unaffected 60	Sand, gm 53.1
Explosion Temperature: 'C	Sensitivity to Initiation:
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, gm
1	Mercury Fulminate
5 Decomposes 280	Lead Azide 0.20
10 15	Tetryl 0.08
20	Bellistic Morter, % THT: (a) 126
75°C International Host Test:	Trous Test, % TNT: (b) 117
73°C International Moor Foot: % Loss in 78 Hrs	Mote Dent Test: (c)
A month of the title	Method B
100°C Heat Test:	Condition Hand tamped
	Confined No
	Density, gm/cc 1.57
,	Brisance, % TNT 118
Explosion in 100 Hrs None	
	Detenotion Rate: (d)
Elementille, index.	Confinement None
Flammobility Index:	
	Condition Hand tamped
	Condition Hand tamped Charge Diameter, in. 1.0
Flammobility Index: Hygroscopicity: % 30°C, 95% RH 2.4 Volcatility: 25°C, 5 days 1.15	Condition Hand tamped

regimentation Test:		Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projestile, Let	WC-91:	Glass Cones Stee! Cones
Density gm/cc	158	Hole Volume
Charge Wt, Ib	2045	Hole Depth
Total No. of Fragments:		Color: Yellov
For TNT	703	terror.
rox Subject HE	944	Principal Vess: Plastic desolition emplosive
3 inch HE, MASAT Projectile, Le	e KC-5:	Principal Uses: Plastic demolition explosive
Density, gm/cc	1.60	
Charge Wt, Ib	0.842	
Total No. of Fragments:		
For TNT	514	Method of Looding: Hand tamped
For Subject HE	671	
. or ourgont 11%		Leading Density: gm/cc 1.58
regment Velocity: ft/soc		``
At 9 ft At 251/4 ft		Street:
Density, gm/cc		
Duraity, gm/sc		Method Dry
lest (Relative to TNT):		Hazard Class (Quuntity-Distance) Class 9
Air:		Compatibility Group Group I
Peak Pressure	10 5	
Impulse	109	Exudation Exudes at 77°C
Energy	20,	
Ale Comitmed		Plasticity:
Air, Confined: Impulse		Below 0°C Hard (-29°c)
···· p. 2 iu u		Below 0°C Hard (-29°C) 0-40°C Plastic
Under Water:		Above 40°C Exudes (77°C)
Peak Pressure		
Impulse		Booster Sensitivity Test: (h)
Energy		Condition Pressed Tetryl. sm 160
Underground:		Tetryl, gm 100 Wax, in. for 50% Detonation 1.36
Peak Pressure		Density, gm/cc 1.62
Impulse		
Energy		References:
,		See references for Composition C-4.

leuspealitions 96	Meieculer Weight:
RIX 91	Oxygen Selence: CO ₂ %
Plasticizer, non- explosive 9*	CO % Density: gm/cc
* Contains polyisobutylene 2.15; mod 1.65 and di(2-ethylhexyl) sebacat	or oil
C/H Ratio	Freezing Point: *C
mpost Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+	Beiling Point: 'C
Sample Wt 20 mg	Refractive Index, no
Picatinny Arsenal Apparatus, in. 19 Sample Wt, mg 27	n _s
	n
Friction Pandulum Test:	Vocuum Stability Test:
Steel Shoe Unaffected	cc/40 Hrs, at
Firm Shoe Unaffected	90°C
Riffe Bullet Impact Test: Trials	100°C 0.26
%	120 C
Explosions 0	135°C
Purtials 0	150°C
Burned 20	200 Grem Bomb Send Test:
Unaffected 80	Sand, gm 55.7
Explosion Temperature: °C	Sensitivity to Initiation:
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, gm
1 5 290	Mercury Fulminate
5 290 !0	Lead Azide 0.20
:0 15	Tetryl 0.10
20	Ballistic Mc:ter, % TNT: (a) 130
	Treuzi Test, % TNT:
75°C Interpolational Heat Test: % Loss in 48 Hrs	Plate Cent Test: (c)
,	/Method E
100°C Here Test:	Condition Hand tamped
% Loss, At 48 Hrs 0.13	
% Len, 2n1 48 Hrs 0.00	
Explicion in 100 Hrs Rone	Brisance, % TNT 175
The same of the sa	Detenation Rate: (d)
Flammability Index:	Confinement
Hygrescopicity: % 30°C, 95% RH N11	Condition Hand temped
MII det in designation of the continuent of the	Charge Diameter, in. 1.0
	Density, gm/cc 1.59

Progmentation Yes*	Shoped Charge Effectives	ness, TNT = 100;	
90 mm HE, M71 Projectile, Let WC-91:	Gloss Co	ines Stret Cories	
Density, gm/cc	Hole Volume		
Charge Wt, Ib	Hole Depth		
ral Nr. of Fragments:	Celer:	Light brown	
For TNT	•	776#4 010#4	
For Subject HE	Principal Uses: Plastic	c demolition explosi	ve
3 inch HE, M42A1 Projectile, Let KC-S:			
Density, gm/cc			
Charge Wt, Ib			
Total No. of Fragments:	Method of Looding:	***************************************	
For TNT	manual or Locality:	Hand tamped	
For Subject HE			- , - ,
	Leeding Density: gm/cc	1.60	
ingment Velocity: ft/sec At 9 ft			
At 251/2 ft	Storage:		
Density, gm/cc	Methr d	Dry	
last (Relative to TNT):	Hazard Class (Quantity	-Distance) Class 9	
Air:	Compatibility Group	Group I	
Peak Pressure		0	
Impulse	Exudation	None at 77°C	
Energy		-	
Air, Conflant: Impulse	Effect of Temperatur Rate of Detonation:	re on (i)	
Under Weter:	16 hrs at, °C	-54 21	
Peak Pressure	Density, gm/cc Rate, m/sec	1.36 1.35 7020 7040	
Impulse		1020 1040	
Energy	Plasticity:		
Underground:	Below 0°C	Plastic (-57°C)
Peak Pressure	0-40°C Above 40°C	Plastic Plastic (7.00)	
Impulse		1111010 (1, 0)	
Energy			
	i		
	i		
	İ		

Preparation:

In manufacturing Composition C-3, the mixed plasticizing agent is heated in a melting kettle at 100°C. Water-wet RDK is added and heating and stirring are continued until all the water is evaporated. This mixture is then cooled and hand pressed into demolition blocks or special item assumition.

Composition C-4 is prepared by hand kneeding and rolling, or in a Schreder Bowl mixer, RDX of 44 micron size or less with the polyisobutylene-plasticizer previously made up in ether. The thoroughly blended explosive is dried in air at 60°C and loosely packed by hand tamping to its maximum density.

Origin:

Developed by the British during World War II as a plastic explosive which could be hand shaped. It was standardized in the United States during World War II and subsequent development led to mixtures designated C-2, C-3 and C-4.

Destruction by Chemical Decomposition:

Composition C-3 is decomposed by adding it slowly to a solution composed of 1 1/4 parts sodium hydroxide, 11 parts vater, and 4 parts 95% alcohol, heated to 50°C. After addition of Composition C-3 is complete, the solution is heated to 80° C and maintained at this temperature for 15 minutes.

References: 11

- (a) Committee of Div 2 and 8, H To, Report on HMX and Tritonal, OSRO No. 5406, 31 July 1945.
- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
 - (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (d) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, GURD Report No. 1219, 22 February 1943.
- M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.
- (e) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (f) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-0RD-3723.
- (g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, 18 September 1943, NIPC Contract W-672-ORD-5723.
- (h) L. C. Smit and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

liSee footnote 1, page 10.

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Compositions C, r-2, C-3, C-4

- (i) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Temperatures, PATR No. 2303, November 1956.
 - (j) Also see the following Picatinny Arsenal Technical Reports on RDX Composition C:

	<u>o</u>	<u>1</u>	3	4	2	<u>6</u>	I	<u>8</u>	2
Comp C	1260		1293					1518 18 3 8	
Comp C-2		1611	1293	O) Els	3.505	1416	1000	1518	
<u>case (2)</u>		TOTT	1713	2154	1595 1695	1416 1556 1766	1797	1518 2028	
Comp Cal					1885	1766 1766	1907	1838	1819
								1958	

Copper Chlorotetrasole

Composition:	Melecular Weight: (CuCgNgCl2)	271			
% C 8.9 N — N	Oxygen Belence:				
(i) Sccr	CO, %	-30 -18			
и 41.5 йи					
CI 26.2 K—N	Density: gm/cc	2.04			
Cu 23.4 H _ H	Melting Point: °C				
C/H Ratio	Freezing Point: *C				
Impect Sensitivity, 2 Kg Wt: Bureou of Mines Apporatus, cm	Beiling Point: 'C				
Sample Wt 20 mg Picotinny Arsenal Apparatus, in: 1; (1 1b wt) 3 Sample Wt, mg 9	Refrective Index, ng. ng. ng.				
Friction Pendulum Test:	Vecuum Stability Test:				
Steel Shoe Exploded	cc/40 Hrs, at				
Fiber Shoe Exploded	90°C				
Rifle Sullet Impact Test: Triols	100°C				
%	120°C 135°C				
Explosions	150°C				
Partials					
Burned	200 Gram Bomb Sand Tost: (f)	05.0			
Unaffected	Sond, gm Black powder fuse 27.4	25:3 17:0			
Explosion Temperature: °C	Sensitivity to Initiation:				
Seconds, 0.1 (nu cop used)	Minimum Detonating Charge, gm				
1 5 305	Mercury Fulminate Lead Azide 0.20	0.30			
10	Lead Azide 0.20 Tetryl 0.10	0.30			
15					
20	Bellistic Morter, % TNT:				
75°C International Host Test:	Trouzi Test, % TNT:				
% Loss in 48 Hrs	Piete Dent Test: Method				
00°C Heat Test:	Condition				
% Loss, 1st 48 Hrs 2-67	Confined				
% Loss, 2nd 48 Hrs 0-10	Density, gm/cc				
Explosion in 100 Hrs None	Brisance, % TNT				
Flommability Index:	Dutonation Rate: Confinement				
	Condition				
Hygroscopicity: % 30°C, 90% RR 3.11	Charge Diameter, in.				
Walastita	Density, gm/cc				
Volatility:	Rate, meters/second				

Copper Chlorotetrasole

regmentation Test:	Skaped Cherye Effectiveness, TNT :	± 100:		
90 mm HE, M71 Projectile, Let WC-91:	Glass Cones Ste	ol Cones		
Density, gm/cc	Hole Volume			
Charge Wt, Ib	Hole Depth	<i>i</i>		
Tetal No. of Fragments:	Colors	lee		
For TNT		T		
For Subject HE	Principal Uses: Primary explosive			
3 inch HE, M42A1 Projectile, Let KC-S:				
Density, gm/cc	l			
Charge Wt, Ib		· ·		
Total No. of Fragments:	Method of Leading: Pressed			
For TNT				
For Subject HE	Leading Density: gm/cc psi x 10 ³ (c)			
regment Velocity: ft/sec	10 20 40 1.49 1.63 1.74	70 1.86		
At 9 ft At 251/ ₆ ft	Storogn:			
Density, gm/cc	Method	Wet		
lest (Relative to TNT):	Hazard Class (Quantity-Divisions)	Ciass 9		
Aire	Compatibility Gray	Group M		
Peak Pressure	6. 4.N			
Impulse	Exudation	None		
Energy				
Air, Confined:	Stab Sensitivity:	(e)		
Impulse	Density Firing Point (in	ich-ounces)		
	<u>ga/cc 05 505</u>	1005		
Under Weter: Peak Pressure	1.49 9 11	15		
	1.63 8.5 10	12		
tmpuis. Energy	1.74 6	- 9 6		
धक्काश्चर	1.86	6		
Underground: Pack Preseure	Heat of:			
Impulse	Explosion, cal/gm	432		
Energy	Specific Heat, cal/gm/°C			
	Temp range C ^O -3C ^O C Wt of *emple, go	0.155 0.8910		

Properation: (a)

Five grams of 5-aminotetrasole are dissolved in a mixture of 200 ml of water and 70 ml of concentrated BCL. Prough heroseme or nujol (which gives a slightly cleaner product) is added to provide a layer of oil approximately $1/h^{\rm m}$ thick on the surface. With only moderate stirring and external cooling to 10^{0} - 15° C, a solution of 5 grams of sodium nitrite in 70 cc of water is added rapidly by means of a burette extending below the oil layer. Immediately after this addition, a solution of 5 grams of cupric chloride in a minimum amount of water is added all at once, and stirring is continue, for about I hour. The reading is allowed to stand for a few minutes till the bright blue copper salt separates. The oil is removed by decantation and may be reused. The salt is filtered; washed with water alcohol, and either; and dried - giving a yield of 6 grams or 7h%.

Origin:

3,46

The copper salt of 5-chlorotetrazole was first described in 1929 by R. Stolle (with E. Schick, F. Henke-Stark and L. Krauss) who prepared the compound by reaction of the diazonium chloride of 5-aminotetrazole with copper chloride (Ber 62A, 1123).

References: 12

- (a) R. J. Gaughran and J. V. R. Kaufman, Synthesis and Properties of Halotetrazole Salts, PATR No. 2136, February 1955.
- (b) A. M. Anzalone, J. E. Abel and A. C. Forsyth, Characteristics of Explosive Substances, for Application in Assumition, PATR No. 2179, May 1955.
- (c) A. C. Forsyth, Pfc, S. Krasner and R. J. Gaughran, Development of Optimus Explosive Trains. An Investigation Concerning Stab Sensitivity versus Loading Density of Some Initiating Companies, PATR No. 2146, February 1955.

¹²See foutnote 1, page 10.

Cyanuric Triazide

Composition:	Molecular Weight: (C3N12) 204
c 17.6 N ₂	Oxygen Belence:
13	CO ₂ % -47.1 CO % -23.5
и 82.4	
и	Jensity: gm/cc Crystal 1.54
ng-c c-ng	Molting Point: °C 94
C/H Ratio	Freezing Point: *C
Impact Sensitivity, 2 Kg Wt: Bureou of Mines Apparotus, cm 1 kg vt 7	Builing Faint: 'C
Sample Wt 20 mg	Refrective Index, no
Picatinny Arsenal Apparatus, in	n _m
Sample Wt, mg -	n <u>o</u>
Friction Pandulum Test:	·
Steel Shoe	Vocuum Stebility Test: cc/40 Hrs, at
Fiber Shoe	90°C
	100°C
Riffle Bullet Impact Test: Trials	120°C
% European	125°C
Explosions Partials	150°C
Burned	200 Grem Bomb Sond Test:
Unaffected	Sand, gm 32.2
Explacion Temperature: *C Seconds, 0.1 (no cop used) 252	Sensitivity to Initiation: Minimum Detonating Charge, gm
1	Mercury Fulminate -
5	Lead Azide 0-20
10	Tetryi 0.10
15	
20	Bellistic Morter, % TNT:
	Trouzi Test, % TNT:
75°C International Heat Tast: % Loss in 48 Hrs	Plate Dest Test: Method
	Condition
100°C Heat Test:	Confined
% Loss, 1st 48 idrs	Density, gm/cc
% Loss, 2nd 48 Hrs.	Brisance, % TNT
Explosion in 100 Hrs	
Flammability Index:	Detenation Rate: Confinement
	Condition -
Hygrescepicity: %	Charge Diameter, in. 0-3
	Density, gm/cc 1-15
Voistility: Decomposes above 100°C	Rate, meters/second 5550-5600

Cyanuric Triazide

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth
Total No. of Fragments: For TNT For Subject HE	Colorless
3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib	Principed Uses: Not used because of difficulty in controlling sensitivity.
Total No. of Fragments: For TNT For Subject HE	Method of Looding: Pressed
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Leeding Density: gm/cc At 200 atmospheres 1.4 At 800 atmospheres 1.5 Storage:
West (Reintive to TNT):	Method Hozard Class (Quantity-Distance) Class 9
Air: Peak Pressure Impulse Energy	Compatibility Group Exudation None
Air, Confined: Impulse	
Under Weter: Peak Pressure Impulse Energy	
Underground: Peak Pressure Impulse	
Energy	

Preparation:

By the reaction of cyanuric chloride with an aqueous solution of sodium aside:

Recrystallization should be avoided as it leads to very large crystals which explode when broken.

Origin:

Cyanuric Triszide was prepared in 1847 by Cahours from chlorine and methyl cyanate. Later James improved the process (JCS 51, 268 (1887) and in 1921 E. Ott patented the preparation from cyanuric chloride and sodium axide (Ref b) Taylor and Rinkenbach prepared cyanuric triszide in a pure state and determined its properties (Ref c).

Initiating Efficiency:

Reported to be more efficient than lead axide. Capable of initiating Explosive D.

Solubility:

Insoluble in water; readily soluble in hot ethanol, acetone, benzene, and ether.

Heat of:

Formation, cal/gm

-1090 to -1138

References: 13

- (a) A. H. Blatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.
 - (b) Ott and Ohse, Ber 54, 179 (1921).
 - (c) Taylor and Rinkenbach, Bureau of Mines, RI 2513 (1923). Taylor and Rinkenbach, J Frank Inst 204, 369 (1927).

¹³See footnote 1, page 10.

Composition:		Meloculor Weight: (C3H6N6O6)	555
C 16.3 02N-N N-N	100	Oxygen Balance:	
-	2	CO ₂ %	0.0 -22
H 2.7 H ₂ ¢ CH ₂		CO 18	
и 37.8		Density: gm/cc Crystal	1.82
0 43.2 NO ₂		Melting Point: *C	204
C/H Ratio 0.095		Freezing Point: "C	
impact Sanshivity, 3 Kg Wt:	20	Beiling Point: *C	
Bureau of Mines Apparatus, cm Sample Wt 20 mg	32	Refrective Index, no	
Picatinny Arsenal Apparatus, in.	8	nº	
Somple Wt, mg	18	· · · · · · · · · · · · · · · · · · ·	
		n <u>s</u>	
Frietion Pendulum Test:		Vacuum Stability Test:	
Steel Shoe Explode		cc/40 Hrs, at 90°C	
Fiber Shoe Unaffec	tel	100°C	0.7
Riffe Buffet Impact Test: Trials		120°C	0.9
%		135°C	-
Explosions 100		150°C	2.5
Portials 0			
Burned 0		200 Gram Bomb Sond Yest:	(0.0
Unaffected 0		Sand, gm	60.5
Explosion Temperature: *C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used) 405		Minimum Detonating Charge, gm	
1 316		Mercury Fulminate	0.19 [®]
5 Decomposes 260		Lead Azide	0.05*
10 240		Tetryl * Alternative initiating char	- Fes.
15 235 20 -		Bollistic Morter, % TNT: (a)	150
		Trousi Test, % TNT: (b)	157
75°C International Heat Test:	0.00	Plate Dent Test: (c)	······································
% Loss in 48 Hrs	0.03	Method	A
100°C Heat Test:		Condition	Pressed
% Loss, 1st 48 Hrs	0 04	Confined	Yes
% Loss, 2nd 48 Hrs	0.00	Density, gm/cc	1.50
Explosion in 100 Hrs	None	Prisonce, % TNT	1 3 5
		Detenation Rate:	
Flammability Index: (d)	278	Confinement	None
		Condition	Pressed
Hygrescopicity: % 25°C, 100% RH	0.02	Charge Diameter, in.	1.0
		Density, gm/cc	1.65
Veletility:	Nil	Density, grit/CC	1.0)

^{*}Name given by Clarence J. Bain of Picatinny Arsenal. Germans call it Hexogen; Italians call it T4; British, RDX.

Cyclonite (RDK)

Secretar Scholistiny Yest:	Decemposition Equation: (1) Oxygen, atoms/sec 10 ¹⁸ .5
Condition	Oxygen, atoms/sec 10 ¹⁰⁺³
Tetryi, gm	Heat, kilocolorie/mole 47.5
Wax, in. for 50% Detonation	(AH, kcat/mol)
Wax, gm	Temperature Range, *C 213-299 Phase Idout d
Density, gm/cc	Phase Liquid
Next of: Combustion, col/gm 2285	Armor Plate Impact Test:
Explosion, cel/gm 1280	
Gas Volume, cc/gm 908	60 mm Merter Projectile: 50 % Inert, Velocity, ft/sec
Formation, cal/gm -\$5	Aluminum Fineness
Solution, cal/mol (28-55% HN) ₂) 7.169	
Assuming cyclonite unimolecular	500-16 Genarel Purpose Bombs:
Specific heat: col/gm/*C	Plate Thickness, inches
<u>°c</u>	Trace Principals, market
20 0.298 100 0.406	1
40 0.331 120 0.427	11/4
60 0.360 140 0.446 80 0.384	11/2
	13/4
Burning Rate:	
cm/sec	Somb Drop Test:
Thermal Conductivity: (h)	
col/sec/cm/°C 1.263 6.91 x 10 1 Density, gm/cc 1.533 6.98 x 10	177, 2000-ib Semi-Armer-Piercing Bemb vs Concrete:
Coefficient of Expension:	Max Safe Drop, ft
Linear, %/°C	500-lb General Purpose Bomb vs Concrete:
No W 400	No.
Volume, %/*C	Height, ft
Hardness, Mohe' Scale: 2.5	Trials
	Unaffected
Young's Medulus:	Low Order
E', dynes/cm²	High Order
E, Ib/inch ²	1000-th General Purpose Somb vs Concrete:
Density, gm/cc	1500 to Gamera 1 arport from 15 constitute
	Height, ft
Coopposalve Strength: Ib/inch ²	Trials
- -	Unaffected
Vagar (resource:	Low Order

Cyclonite (RDK)

regmentation Test:	Shaped Charge Effectiveness, TNT = 100:
90 man HE, M71 Projectile, Let WC-91:	Glass Cones Steel Cones
Density, gm/cc	Hole Volume
Charge Wt, Ib	Hole Depth
Total No. of Progments:	Color: White
For TNT	will of
For Subject HE	Blacked Here Petersten have shown and
De-C MR AARRAS Districts Line MR Di	Principal Uses: Detonator base charge, and ingredient for projectile and
3 inch HE, M42A1 Projectile, Let KC-5:	bomb fillers
Density, grn/cc	
Charge Wt, Ib	
Total No. of Fragments:	Method of Leading: Pressed
For TNT	wanted & creamily.
For Subject HE	
	Leeding Dunnity: gm/cc pai x 10 ³ 5 10 12 15 2
Fragment Velocity: ft/sec	3 5 10 12 15 2 1.46 1.52 1.60 1.63 1.65 1.6
At 9 ft	Storage:
At 251/4 ft	Sauce.
Density, gm/cc	Method Wet
Heat (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9
A1	Corncatibility Group Group M (vet)
Air: Pack Pressure	Group L (dry)
Impulse	Exudation None
Energy	
	Effect of Temperature on
Air, Confined: Impulse	Rate of Detonation: (k)
m pane	16 hrs at, °C -54 21
Under Water:	Density, gm/cc 1.61 1.62
Peak Pressure	Rate, m/sec 8100 8050
Impulse	Effect of Temperature on
Energy	Impact Sensitivity:
Underground:	Temp. PA Impect Test
Peak Pressure	OC 2Kg Wt, inches
Impulse	Room 9
Energy	32.2
	104 5

Cyclonite (RDX)

Solubility of Cycl	onite; gm/100 gr	of the follow	ing substances	<u>ı:</u> (j)
Nater	Alcohol	Acetone	Benzene	Tolueno
90 0.005 90 0.025 70 0.075 90 0.19 100 0.28	0 0.040 20 0.105 40 0.240 60 0.579 78 1.195	0 4.4 20 7.3 40 11.5 60 18.	©	0 0.015 20 0.02 40 0.05 60 0.13 80 0.30 100 0.65
Ethyl acetate	tetrachloride	Methanol	Ether	THT
28 2.9 94 18.	°c <u>≰</u> 50 0.005 60 0.007 70 0.009	oc ≰ 0 0.14 20 0.23 40 0.47 50 1.1	0c <u>\$</u> 10 0.05 20 0.056 30 0.076	80 4.4 85 5.0 90 5.55 95 6.2 100 7.0
lsoamyl alsohol	Methyl acetate	-Ethoxyethyl acetate	Chlorobenzene	Trichloro- ethylene
°C	oc ≰ 20 2.9 30 3.3 40 4.1 50 5.6	00 4 20 0.15 30 0.16 40 0.19 50 0.25	°C	00 ± 0.20 0.20 0.22 40 0.24 50 0.26
Tetra- chloroethane	Isopro- panol	Isobutanol	Chloroform	Mesityloxide
o _C	°C 4 38 0.18	°c 4	°C	°C ≰ 27 3.2 97 12.2
Cyclo- hexanone	<u> Hi tro-</u> benzene	Mitro- ethene	Cyclo- pentanone	Acetonitrile
0 _C <u>1</u> 12.7 97 25	oc 4 25 1.5 97 12.4	oc 4 28 3.6 93 19	o _C ≰ 28 11.5 90 37	°c ≰ 28 11 82 33
	Methyl	ethyl ketone		
	°c 28	\$ 5.6		

Cyclonite (RDX)

Solubility of Cyclonite, Holston Lot E-2-5 in Various Solvents:

Solubility gm/100 gm Solvent

Solvent	Point,	Grade or Source	28°0	Heated	Crystalline Form
Acetone	56	CIP CIP	8.2	16.5 at 60°C	hexagonal-thick
Cyclobess:none	155.6	CP CP	13.0	24.0 at 9300	cubic (massive form)
Mi trome thane	100.8		Ĭ.5	12.4 at 97°C	plates
Acetonitrile	81.6	Miacet Chem. Co.	11.3	33.4 at 93°C	plates
1-Mitropropane	126.5	EK Pract	1.4	10.6 at 93°C	abant
2-Mitropropane	120.	EK Prac:	2.3	11.6 at 93°C	short needles
2,4-Pentanedione	140.5	Carbide &	2.9		short needles
	140.9	Carbon	2.9	18.3 at 93°C	flat prises
Methylisobutylketone	115.8		2.4	9.6 at 93°C	long prisms
n-Propylacetate	101.6	EK Red Label	1.5	6.0 at 93°C	long prisms, some cubic
n-Butylformte	105.6	EK Red Label	1.4	4.6 at 93°C	long prisms
Ethyl acetate	77.1	Baker's P	2.0	6.1 at boil.	hexagonal plates
n-Propylpropionate	121	EK Red Label	0.8	1.6 at 93°C	short prisms, some
Butylacetate	126.5	El Technical	1.1	4.0 at 93°C	long prisms
Methylethylketone	79.6		5.6	13.9 at boil.	coarse plates
Mitroethane	114.2	EK Red Label	3.6	19.5 at 93°C	plates
Isopropylacetate	88-90	CIP	1.1	3.2 at boil.	long prisms
Mesityloxide	128	EX Red Tabel	4.8	14.5 at 93°C	plates
n-Amylacetate	146	CIP .	1.0	2.1 at 93°C	prisms
Dimethylcarbonate	88-91	EX Red Label	1.4	6.6 at boil.	plates
Diethylcarbonate	125-126.5	EK Red Label	0.7	3.2 at 93°C	prisms
Isonmylacetate	132	CIP	1.2	3.6 at 93°C	prisms
Ethylpropionate	98-100	EK Red Label	3.0	10.7 at 93°C	fairly thick hex
Methyl-n-butyrata	101.5-103.5	EK Red Label	1.2	4.9 at 93°C	plates needles
Cyclopentanone	130.6	EK Red Label	11.5	39.0 at 93.500	
Acrylonitrile	77.3	Cyanamid Cc.	4.0	16.4 at boil.	flat plates
Methylcellosolveacetat		Carbide &	1.6	8.8 at 93°C	massive hexagons and
-	•	Carbon		212 22 75 0	prisms

^{*} EK, Eastman Kodak; Pract, practical.

Preparation:

(Summary Technical Report of the NDRC, Div 8, Vol 1)

Ammonium nitrate and acetic anhydride are placed in a flask and, while the mixture is stirred at 75°C, the following three liquids are introduced concurrently and proportionately: acetic anhydride, concentrated nitric acid, and a solution of hexamine in glacial acetic acid. The final mixture is held for a short time at 75°C, diluted with water to 30% acetic acid, and simmered to hydrolyze unstable reaction by-products, which are a mixture of various nitrated and acetylated derivatives of hexamine fragments. After simmering, the slurry is cooled and the precipitated cyclonite removed by filtration. The yield is 78% of the theoretical amount (2 moles) of cyclonite melting at 199°C. By dissolving the ammonium nitrate in the nitric acid, a continuous process, based on 3 liquids, is possible.

The product is recrystallized from acetone, or cyclohexanone, to (a) remove acidity, (b) control particle size and (c) to produce stable \$\int_{\text{-HMX}}\$. The preparative procedure described above, the Bachmann or Combination process, yields cyclonite containing 3-84 HMX.

Origin:

First prepared by Henning in 1899 (German Patent 104,280) and later by von Hertz (U. S. Patent 1, 402,693) in 1922 who recognized its value as an explosive. Not used on a large scale in explosive ammunition until World War II.

Destruction by Chemical Decomposition:

Cyclonite (RDX) is decomposed by adding it slowly to 25 times its weight of boiling 5% sodium bydroxide. Boiling should be continued for one-half hour.

References: 14

- (a) I. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
 - (b) Ph. Haoum, Z. ges Schiese Sprengstoffe, pp. 181, 229, 267 (27 June 1932).
 - (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

¹⁶ See footnote 1, page 10.

Cyclonite (RDX)

- (e) Argument Research Department (Woolwich), Solubility of RDK in Nitric Acid (ARD Expl Rpt 322/43 September 1943).
 - (f) Report AC-2587.
 - (g) <u>International Critical Tables</u> Land. Bornat.
- B. T. Fedoroff et al, A Manual for Explosives Laboratories, Lefax Society Inc, Philadelphia, 1943-6.
- (h) E. Rutchinson, The Therrel Sensitiveness of Explosives. The Thermal Conductivity of Explosive Materials, AC 2001, First Report, August 1942.
- (i) R. J. Finkelstein and G. Gemow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.
 - (j) <u>International Critical Tables</u>.
- (k) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.
 - (1) Also see the following Picatinny Arsenal Technical Reports on Cyclonite:

<u>o</u>	<u>1</u>	<u>2</u>	3	<u>4</u> .	2	<u>6</u>	I	8	2
1170 1290 1360 1450 1760 1980 2100	1211 1241 1311 1421 1481 1561 1651 1741 1751 1761 2131 2151	582 1342 1352 1372 1402 1452 1492 1532 2062 2112	863 1193 1293 1433 1483 1503 1503 1713 1793 1923	1184 1414 1634 2024 2154 2204	65 1175 1185 1435 1445 1715 1855 1885 1915 1935 2095 2125 2205	1236 1316 1416 1446 1466 1476 1556 1756 1756 1796 1836 1936 1936 2056 2176	857 1207 1427 1437 1517 1617 1687 1737 1787 1787 1797 1957 2147 2227	1436 1458 1498 1578 1838 1958 2008 2028 2178 2198	709 1379 1429 1449 1469 1709 2059 2179

75

Cyclotol, 75/25

Composition:	Melecular Weight: 224	
% 75	Oxygen Belance:	
RDX 75	CO, % -35 CO % - 6	
TNT: 25	Dennity: gm/cc Cast 1.71	
	Moliting Palet: *C	
C/H Rotio	Freezing Point: *C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	Bohing Peint: *C	
Sample Wt 20 mg	Refrective Index, no	
Picatinny Arsenal Apparatus, in. Sample Wt, mg	n _m	
	n	
Frictive Pendulum Test:	Vocuum Stability Test:	
5 eel Shoe Unaffected	cc/40 Hrs, at	
Fiber Shoe Unaffected	90°C 100°C 2.23	
Rifle Bullet Impact Test: Trials	120°C 0.11	
%	135°C -	
Explosions 30	150°C -	
Partials Smokes 40		
Burned 0 Unaffected 30	200 Grem Bomb Sand Test: Sand, gre	
Explosion Temperature: °C	Sensitirity to Initiation: Minimum Detonating Charge, gm	
Seconds, 0.1 (no unp used)	Mercury Fulminate	
5	Lead Azide	
10	Tetryl	
15	Ballistic Marter, % TNT:	
20	Transl Test, % TNT:	
75°C International Heat Test:	Plate Deat Test:	
% Loss in 48 Hrs	Method	
100°C Heat Test:	Condition	
% Loss, 1st 48 Hrs	Confined	
% Loss, 2nd 48 Hrs	Density, gm/cs	
Explosion in 100 Hrs	Brisance, % TNT	
	Confinement None None	
Floremobility Index:	Continerrant with white	
Floremability Index:		
Floremobility Index: Hygroscopicity: %	Condition Cast Cast	

Cyclotol, 75/25

Receiver Sensitivity Test: Condition	Decemposition Equation: _Oxygen, atoms/sec
Tetryl, gm	(Z/sec)
	Heat, kilocalarie/male
Wax, in. for 50% Detanation	(ΔH, kcal/mol)
Wax, gm	Temperature Range, °C
Density, gm/cc	Phase
Heat of:	Armor Plate Impact Test:
Combustion, col/gm 2625*	The state of the s
Explosion, cal/gm 1225*	60 mm Mortor Projectile:
Gas Volume, cc/gm 862	50% Inert, Velocity, ft/sec
Formation, cel/gm	Aluminum Fineness
Fusion, col/gm (h) 5.0	
*Calculated from composition of mixture.	500-lb General Purpose Sembs:
Specific Heat: cal/gm/°C (h)	
<u>°c</u>	Plate Thickness, inches
-75 0-220 75 0.352	1
0 0.225 85 0.325	
25 0.25¼ 90 0.33½	11/4
50 0.296 100 0.351	1½
Burning Rate:	1¾
cm/sec	
	Bomb Drop Test:
Thormal Conductivity:	
cal/sec/cm/°C	17, 2000-th Semi-Armer-Piercing Bemb vs Concrete:
Coefficient of Expension:	Max Safe Drop, ft
Linear, %/°C	500-lb General Purpose Bomb vs Concrete:
Volume, %/°C	
	Height, ft
Hardness, Mahs' Scale:	Trials
	Unaffected
Young's Moduler:	Low Order
E', dynes/cm²	High Order
E, lb/inch ^a	1000 B. Connect Burner B. A. G.
Density, gm/cc	1000-lb General Purpose Somb vs Concrete:
	Height, ft
Compressive Strongth: lb/inch²	Trials
	Unoffected
Vapor Pressure:	Low Order
*C mm Mercury	High Order

Cyclotol, 75/25

Fragmentation Test:		Shaped Charge Effectiveness, TMT =	100:
90 mm HE, M71 Projectile, L	of WC-91:	Glass Cones Steel	Cones
Density, gm/cc	1.72	Hole Volume	
Charge Wt, tb	5.55	Hole Depth	
Total No. of Fragments:		Color: Yallin huge	
For TNT	703	Yellow-buff	
For Subject HE	1514	Principal Utas: Shaped charge b	omb especially
3 inch HE, M42A1 Projectile,	Let KC-5:	fragmentation; grenades	
Density, gm/cc		grenades	•
Charge Wt, Ib		·	
Total No. of Fragments:		Method of Looding:	Cast
For TNT For Subject HE			•
		Leading Density: gm/cc	1.71
Fragment Velocity: ft/sec At 9 ft			
At 251/2 ft		Storogo:	
Density, gm/cc		Method	Dry
Blast (Relative to TNT):	(d)	Hazard Class (Quantity-Distance)	Class 9
Air:		Compatibility Group	Group I
Peak Priss /re	111		
Impuise	126 .	Erudation	
Energy		Preparation: See Composition B	
Air, Confined:			
1mpulse		Origin: Developed by the Briti Wars I and II and standardi States early in World War I	zed in the Unite
Under Weter: Peak Pressure		Black Modulus at Room Temperature (25°-30°C):	
Impulse Energy	•	Dynes/cm ² x 10-10 Density, gm/cc	3.09 1.74
Underground:		Absolute Viscosity, poises:* Temp, 85°C	•
Peak Pressure Impuis		90°C	210**
_ '		Efflux Viscosity, Saybolt Seco	nds:
Energy		Тетр, 85°С	9-14
		* Compositions using Spec Grade Class A RDX. ** Composition prepared using Riparticle size.	

Cyclotol, 70/30

Composition:	Melecular Weight:	224
RDX 70	Oxygen Belence:	
10	CO. %	-37
INT 30	CO %	- 8
	Density: gm/cc Cast	1.71
	Melting Point: 'C	
C/H Ratio	Freezing Point: *C	
Impact Sensitivity, 2 Kg Wt: Bureou of Mines Apparotus. cm 60	Boiling Point: *C	
Bureau of Mines Apparatus, cm 60 Sample Wt 20 mg	Refrective Index, no	
Picatinny Arsenal Apparatus, in. 14	<u> </u>	
Sample Wt, mg 20	n _B	
·	n ₃₆	
Friction Pondulum Test:	Vocuum Stability Test:	
Steel Shoe Unaffected	cc/40 Hrs, at	
Fiber Shoe Unaffected	90°C	
Riffe Bullet Impact Yest: Triols	100°C	
·	120°C	0.86
% Explosions 30	135°C	
Partials 30	150°C	
Burned 0	200 Grem Bemb Send Test:	
Unaffected 40	Sand, gm	56.6
P. Mata. B.		75.0
Explosion Temperature: *C Seconds, 0.1 (no cap used) -	Sensitivity to Initiation: Minimum Detonating Charge, g	<u></u>
1 -	Mercury Fulminate	0.21*
5 Decomposes 265	Lead Azide	0.20*
10		0.20*
15	Tetryl *Alternative initiating char	rges.
20	Ballistic Morter, % TNT: (a)	135
	Trenzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: (b)	_
	Method	В
100°C Heet Test:	Condition	Cast
% Loss, 1st 48 Hrs 0-07	Confined	No
% Loss, 2nd 48 Hrs 0.08	Density, gm/cc	1.725
Explosion in 100 Hrs None	Brisance, % TNT	136
	Detonation Rate:	
Flammability Index:	Confinement	None
	Condition	Cast
Hygrescopicity: % N11	Charge Diameter, in.	1.0
Hygroscopicity: % N11 Volatility: N11	Charge Diameter, in. Density, gm/cc	1.0 1.73

Cyclotol, 70/30

regmentation Test:		Shaped Charge Effectiveness, TNT =	: 1 00 2
90 mm HE, MJ: Projectile, La	WC-91:	Gloss Cones Stee	il Cones (e)
Density, gm/cc	1.71	Hole Volume	
Charge Wt, Ib	2.213	Hole Depth	130
Total No. of Fragments:		Color: Y	ellow-buff
For TNT	703	Come:	E(10W-0011
For Subject HE	1165		
3 inch HE, M42A1 Projectile, L	as KC.S.	Principal Uses: Shaped charge be especially frag	
Density, gm/cc	1.72	projectiles, gr	enades
****	0.923		
Charge Wt, It	0.55		
Total No. of Fragments:		Method of Leading:	CABL
For TNT	514		
For Subject HE	828		
		Loading Density: gm/cc	1.71
regment Velocity: ft/sec			
At 9 ft At 251/2 ft		-Storage:	
Density, gm/cc			
Serienty, Willy Co.		Method	Dry
liest (Relative to TNT):	(d)	Hazord Class (Quantity-Distance)	Class 9
	\ ,		
Air:		Compatibility Group	Group I
Peak Pressure	110		
Impulse	120	Exudation	
Energy			
Air, Confired:		Preparation: See Composition	В
Impulse		Origin: Developed by the Brit	
•		World Wars I and II and st the United States early in	
Under Water:			MOLIG MEL 11.
Peak Pressure		Absolute Viscosity, poises:*	
Impulse		Тешр, 85°С 90°С	53.2
Energy		• • •	75
		Efflux Viscosity, Saybolt Sec	
Underground: Peak Pressure		Temp, 85°C	5
Impulse		Heat of:	##
•		Combustion, cal/gm	2685
Energy		Explosion, cal/gm	1213
		Gas Volume, cc/gm	854
		* Composition using Spec Grad	e Type A,

Cyclotol, 65/35

Composition:	Molecular Weight:	224
% RDX 55	Oxygen Belence:	
-	CO: %	-40 - 9
TNT 35	CO 30	- 4
	Density: gm/cc Cast	1.71
	Melting Point: *C	
C/H Ratio	Freezing Point: *C	
Impact Sensitivity, 2 Kg Wt: Bureou of Mine: Apparatus, cm	Boiling Point: *C	
Sample Wt 20 mg	Refrective Index, ng	
Picatinny Arsenal Apparatus, in. Sample Wt. mg	ng.	
	n ₂	
Friction Pendulum Test:	Vocuum Stability Test:	
Steel Shoe Unaffected	cc/40 Hrs, at	
Fiber Shoe Unaffected	90°C	
Riffe Bullet Impact Test: Trials	100°C	
%	120°C	
Explosions	135°C	
Partials	150°C	
Burned	200 Grem Bomb Sand Toot:	
Unoffected	Sand, gm	55.4
Explosion Te aporeture: 'C	Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, g	m
1	Mercury Fulminate	
5 Decomposes 270	Lead Azide	
10	Tetryl	
15	Sellistic Morter, % TNT: (a)	134
20	Trausi Test, % TNT:	1,54
75°C International Host Test:	Plate Dent Test:	
% Loss in 48 Hrs	Method	
	Condition	
100°C Heat Test:	Confined	
% Loss, 1st 48 Hrs	Density, gm/cc	
% Loss, 2nd 48 Hrs	Brisonce, % TNT	
Explosion in 100 Hrs		
Flammability Index:	Detenation Rate:	M
recommendaty insert:	Confinement	None Court
Mygrescopicity: % N11	Condition	Cast
angerous and a second	Charge Diameter, in.	1.0
Volatility: N11	Density, gm/cc	1.72
·	Rate, meters/second	7975

Cyclotol, 65/35

Fragmentelien Test:		Shaped Charge Effectiveness, TNT = 100:		
90 mm HE, M71 Projectile, Le	WC-91:	Glass Cones Steel	Cones (e)	
Density, gm/cc	1.71	Hole Valume		
Charge Wt, Ib	2.253	Hole Depth 13	0	
Total No. of Fragments:		Color: Yellow Y		
For TNT	703	Yellow-b	uff	
For Subject HE	1153	Principal Geo: Shaped charge bot	Principal Mass: Shaped charge howhs:	
3 inch HE, M42A1 Projectile, L	er KC-5:	especially fragm projectiles, gre	entation HE	
Density, gm/cc	1.71	projectites, gre	an Ges	
Charge Wt, Ib	0.922			
Total No. of Fragments:		Method of Leading:	Cast	
For TNT	514		CEST	
For Subject HE	769			
egment Velocky: ft/sec		Looding Density: gni/cc	1.71	
At 9 ft At 25½ ft		Storage:		
Density, gm/cc		and also		
beleny, gm/cc		Method	Dry	
set (Relative to TNT):	*************************************	Hazard Class (Quantity-Distance)	Class 9	
Ain		Compatibility Group	Group I	
Peak Pressure				
Impulse		Exudation		
Energy			<u>.</u>	
Air, Confined:		Preparation: See Composition B		
Impulse		Origin: Developed by the Britis World Wers I and II and stand		
Under Weter:		the United States early in Wo	erdized in Xrld War II.	
Peak Pressure		_		
Impulse		Eutectic Temperature, C:	79	
Energy		gm REX/100 gm TNT	١	
Madaman A.		79°C 95°C	4.16 5.85	
Underground: Peak Pressure			<i>))</i>	
Impulse		Absolute Viscosity, poises:*		
Energy		Тешр, 85°с	30.2	
		90°C	26.0	
Heat of:	*			
Combustion, cal/gm	2755	* Composition using Spec Grade Class A RDX.	Type A,	
Explosion, cal/gm	1205	Crees & UDA.		
Ges Volume, cc/gm	845			
* Calculated from composi	tion of mixture.			

Cyclotol, 60/40

Composition: 96	Melecular Weight:	224
RDX 60	Oxygen Belence:	
	CO. % CO %	-43 10
TNT 40		
	Density: gm/cc Cast	1.68
	Molting Point: °C	
C/H Ratio	Freezing Point: *C	-
npost Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 75	Boiling Point: *C	
Sample Wt 20 mg	Refrective Index, no	
Picetiriny Arsenal Apparatus, in. 14	n <u>n</u>	
Sample Wt, mg 19	nai fr	
riction Pendulum Test:		
Steel Shoe Unat:	Vecum Stability Test: cc/40 Hrs, at	
	Tected 90°C	
	100.C	
Iffe Sullet Impact Test: Trials	120°C	0.29
% Explosions 5	135°C	
Porticis 55	150°C	
Burned 25	200 Carro Barak Card Tara	
Unaffected 15	200 Grem Berab Send Test: Sand, gm	54.6
		74.0
ixplacion Temperature: *C	Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, g	•
5 Decomposes 280	Mercury Fulminate	0.22*
10	Lead Azide	0.20*
15	Tetryl *Alternative initiating cha	rges.
20	Bellistic Morter, % TNT: (a)	1.33
	Trousi Toot, % TNT:	
5°C International Heat Test: % Lost in 48 Hrs	Plate Dent Test: (b)	
	Method	В
90°C Heat Test:	Condition	Cast
% Loss, 1st 48 Hrs	Confined	No
% Loss, 2nd 48 Hrs	Density, gm/cc	1.72
Explosion in 100 Hrs	Brisance, % TNT	132
emmebility index:	Datenation Rate:	
the state of the s	Confinement	None
ygrescopicity: % Nil	Condition	Cast
, ,	Charge Diameter, in.	1.0
elatility: Nil	Density, gm/cc	1.72
	Rate, meters/second	7900

Cyclotol, 60/40

Fregmentetion Test:		Shaped Charge Effectiveness, TNT = 100:		
90 mm HE, M71 Projectile, Let	WC-91:	Glass Cones Steel	Cones (a)	
Density, gm/cc	1.65	Hole Volume 178	162	
Charge Wt, Ib	2.187	Hole Depth 125	148	
Total No. of Fragments:		Color: Yel	low-buff	
For TNT	703		200-022	
For Subject HE	998	Principal Uses: Shaped charge t	omb:	
3 inch HE, M42A1 Projectile, Lei	KC-5:	especially frag projectiles, gr	mentation HE	
Density, gm/cc	1.67	projectizes, gr		
Charge Wt, Ib	0.882			
Total No. of Fragments:		Method of Leading:	Cast	
For TNT	514			
For Subject HE	701			
		Looding Density: gm/cc	1.68	
Fragment Velocity: ft/sec	(c) 2965			
At 9 ft At 25% ft	2800 2800	Storage:		
Density, gm/cc	••	Method	Dry	
Blast (Relative to TNT):	(d)	Hazard Class (Quantity-Distance)	Class 9	
Air:		Compatibility Group	Group I	
Peak Pressure	104			
Impuise	116	Exudation		
Energy	••			
Air, Confined:		Preparation: See Composition	В	
Impulse		Origin: Developed by the Brit	ish between	
		World Wars I and II and sta	ndardized in	
Under Water:		the United States early in	World War II.	
Peak Pressure		Bulk Modulus at Room		
impulse		Temperature (25°-30°C):		
Energy		Dynes/cm ² x 10 ⁻¹⁰	4.14	
Underground: Peak Pressure		Density, gm/cc	1.72	
Impulse		Absolute Viscosity, poises:*		
Energy		Temp, 85°C	12.3	
liest of:	* ``	90°C		
Combustion, cal/gm	2820			
Explosion, cal/gm Gas Volume, cc/gm	1195 845	* Compositions using Spec Crad Class A RDX-	e Type A,	
Compressive Strength: Ib/i	3 ·			

^{*} Calculated from composition of mixture.

Cyclotol, 75/25, 70/30, 65/35

References: 15

- (a) L. C. Smith and E. G. Kyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OCRD Report No. 5746, 27 December 1945.
 - (b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (c) R. W. Drake, <u>Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells</u>, OSRD Report No. 5622, 2 January 1946.
- (d) V. Philipchuk, Free Air Blast Evaluation of ADX-THT-Al, RDX-THT, and THT-Metal Systems, Mational Morthern Summary Report, MM-P-34, April 1956.
- (e) Hastern Laboratory, du Pont, Investigation of Cavity Effect. Section III, Variation of Cavity Effect with Composition, NIRC Contract W-572-ORD-5723.
- (f) W. S. Cramer, Bulk Compressibility Data on Several High Explosives, MAYORD Report No. 4360, 15 September 1956.
 - (g) Also see the following Picatinny Arsenal Technical Reports on Tyclotols:

0	1	2	3	4	2	<u>6</u>	I	8	2
1290 1530	1651 1741	1482	1483 1793 19°3	1824 1834 1944 200 4	1435 1585	1476 1756 1796 1876	1427 1507 1747	1398 1488 1838	1469 1509 1709

(h) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

¹⁵See footnote 1, page 10.

Cyclotrimethylene Trinitrosamine

Composition:	2	Melecular Weight: (C3H6N6O3)	174
ີ້ ຂ 0.6		Oxygen Belunce:	
o-n-n	N-N-0	CO ₂ %	-55
н 3-5	T	CO %	-26
N 48.3 H ₂ C	CH ₂	Density: gm/cc	
0 27.6	1	Melting Point: *C	105 to 107
C/H Ratio 0.12		Freezing Point: 'C	
Impact Sansitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm		Boiling Point: *C	
Sample Wt 20 mg		Refrective Index, no.	
Picatinny Arsenal Apparatus, in.	15 to 22	nº	
Sample Wt, mg	17 to 20	n _m	
Fristian Pandulum Test:		1176	
Steel Shoe	Unaffected	Vacuum Stability Test:	(c)
Fiber Shoe	Unaffected	cc/40 Hrs, at 90°C 0.20	
Fiber 3108	Ottallec red	100°C 9.19	3.71*
Riffe Bellet Impect Test: Trials		*Average value of 5 gm sample to	
%		lized from isosmyl alcohol.	
Explosions			
Partials	,	`	
Burned		200 Gram Bomb Sand Test:	
Unaffected	-	Sand, gm 55	9.2 54.1
Explosion Temperature: *C		Sensitivity to Initiation:	
Seconds, 0.1 (no cop used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	0.200**
5 220	1	Leod Azide	0.100##
10		**Alternative initiating charges	1.
15		Bellistic Morter, % TNT:	12
20			130
75°C International Heat Test:		Trouxi Test, % TNT:	
% Loss in 48 Hrs		Plate Deat Test: Method	
100°C Heet Test:		Condition	
% Loss, 1st 48 Hrs	8.79	Confined	
% Loss, 2nd 48 Hrs	2.98	Density, gm/cc	
Explosion in 100 Hrs	None	Brisonce, % TNT	
· · · · · · · · · · · · · · · · · · ·		- Detenation Rate:	(b)
Florimobility Index:		Confinement	None
		— Condition	Cast
Hygrescepicity: % 30°C, 90% RH	0.02	Charge Diameter, in.	1.2
Veletility:		Density, gm/cc	1.42
		•	

Cyclotrimethylene Trinitrosamine

Fregmentation Test:	Shaped Charge Effectiveness, THT =	100:
90 mm HE, M71 Projectile, Let WC-91:	Glass Cones Stee	Cones
Density, gm/cc	Hale Volume	
Charge Wt, ib	Hole Depth	
Total No. of Fragments:	Calan	
For TNT	Color:	Yellow
For Subject HE	Principal Uses: Ingredient of pr	
3 inch HE, M42A1 Projectile, Let KC-5:	The state of the s	Occure illier
Density, gm/cc		
Charge Wt, Ib		
Total No. of Fragments:	Mathed of Leading: Pressed or o	est with edded
For TNT		t depressants
For Subject HE		-
Fregment Velocity: ft/sec	Leading Density: gm/cc S	ee below
At 9 ft At 25½ ft	Storege:	
Density, gm/cc	Method	Dry
Plant (Relative to TNT):	Hazard Class (Quantity-Distance)	Class 9
Air: Peak Pressure	Compatibility Group	Group M
Impulse	Exudation	None
Energy		none
chargy	Density at Various Pressures	(F)
Air, Confined:	Density at Various Pressures:	10.
Impulse	1b/inch ²	gm/cc
Under Weter:	2,420	1.10
Prok Pressure	4,830	1.23
Impulse	9,070	1.37
_ • · · ·	14,500	1.44
Energy	24,200 33,800	1.53 1.57
01-44-	42,500	1.59
Underground: Peak Pressure	,,,,,	
Impulse	Heat of:	
	0-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1	on 50
Energy	Combustion, cal/gm Explosion, cal/gm	3158 876
	Formation, cal/gm	-914
		,
	,	

Cyclotrimethylene Trinitrosanine

Preparation of Herahydro-1,3,5-Trinitroso-s-triazine Cyclotrimethylene Trinitrosamine: (Reference a)

An ammoniscal solution of an amine is prepared by adding aqueous formaldehyde to ammonium hydroxide. The rate of addition of formaldehyde is regulated to maintain a solution temperature of 30° to 35° C.

Sodium nitrite is dissolved in water and the solution or slurry is then poured into the previously prepared amine-exmonia solution and totally dissolved by stirring. This solution is chilled to below 0°C.

Into a mixed acid solution, previously prepared by dissolving concentrated nitric acid in water and adding concentrated sulfuric acid, all chilled to -9°C, there is added the cold amins-nitrite solution below the surface of the acid mixture. The addition is regulated to take 20 to 30 minutes.

The resulting foamy head of cyclotrimethylene trinitroramine is allowed to sit over the icy spent liquor for 1/2 hour and is then collected on a sintered glass funnel and washed to neutrality. The moist cyclotrimethylene trinitrosamine is removed from the funnel and airdried on filter paper. The dry crude product melts at 105° to 107°C. Recrystallization from isosamyl alcohol gives a pure compound melting at 105° to 107°C.

Origin:

Cyclotrimethylene trinitrosamine was discovered in 1888 simultaneously by Griess and Harrow (Ber 21 (1888), p. 2737) and by Mayer (Ber 21 (1888), p. 2883) when sodium nitrite was allowed to react with hexamethylene tetramine in acid solution. This compound was later studied by Duden and Scherff (Ann 288 (1895), p. 218) and by Delépine who determined its heat of formation, which was negative (Bull Soc chim (3) 15 (1896), p. 1199). Because cyclotrimethylene trinitrosamine could be made at first in very poor yield only, it was a long time before it received consideration for practical application as an explosive. However, the study of cyclotrimethylene trinitrosamine was continued and investigations were made as to its behavior in mixtures with other substances (Prof. D. G. Römer "Report on Explosives," BIOSGP 2-HBC 5742).

Destruction by Chemical Decomposition:

Cyclotrimethylene trinitrosamine is easily decomposed by acid or alkali and even by boiling in water.

Cyclotrimethylene Trinitrosamine

High Temperature Decomposition, 0.02 gm in 10 wl Test Tube:

	Immersed 10 minutes in bath	heated at 50/minute
		Temp. CC
(1)	Melting begins	105
	Decomposition begins	150
	Nitrous gas	160
	Entire decomposition	170
(2)	Some bubbles	110
• •	Very slow decomposition	150
	Decomposes in 2 minutes	200
	Decomposes in 40 seconds	250
	Immediate decomposition	300

Long Term Stability: (b)

Cyclotrimethylene irinitrosamine loosely packed in covered wooden boxes for six years at ambient temperature and protected from the sun:

- 1. Explosi a showed no color change.
- 2. Melting point decreased from 104.5° to $10^{i_1\circ}$ C.
- 3. Coefficient of "Utilisation Practique" decreased from 125.5 to 123.5.
- 4. An Thel Test at 110°C gave no color to iodine starch paper in 15 minutes.

Fusion Tests, Mixtures of Cyclotrimethylene Trinitrosamine and TWT:

Cyclotrimethylene Arinitrosamine, \$	Melting Point, C
10	74
20	i 68
30	62
30 40	55
42	55 (Butectic)
	61
50 60	69
70	77
95	95

Datectic Composition With TNT: (b) Rate of Detonation, meters/second

42% Cyclotrimethylene Trinitrosamine 58% TNT

7,000

Iron powier
 Copper powder
 Aluminum powder

Cvclotrimethylen __initrosamine

Reaction of Cyclotrimethylene Trinitrosamine With Other Materials:

	Slight reaction
	Slight reaction
	Slight reaction
1	 a. Violent decomposition after 2 hours at 10°C b. Violent decomposition after 10 to 15 minutes at 100°C
	No evidence of decomposition after 5 days at 90°C

(p)

Detonation P.te: (b)

Conf nement	Paper cartridge	
C.adition	ressed	
harge Diemeter, in.	1.18	
Rate, meters/second	Density, gm/cc	
5180	0.85	
5760	1.00	
6600	1.20	
7330	1-40	
7600	1.50	
7800	1.57	

4. 2 parts picric acid + 1 part R-Salt

5. 2 parts nitroglycerin + 1 part R-Smlt

References: 1(

- (a) Arthur D. Little, Inc. Progress Report No. 106, Fundamental Development of High Explosives, April 1955, Contract No. DAI-19-020-501-ORD(P)-33.
- (b) Louis Médard and Maurice Dutour, "Étude Des Proprietés De La Cyclotriméthyléne Trinitrosamine," Mém poudr, 37, 1924 (1954).
- (c) H. A. Bronner and J. V. R. Kaufman, "Synthesis and Properties of R-Salt," PATR in preparation 1959.
- (d) Also see the following Picatinny Arsenal Technical Reports on Cyclotri, ω thylene Trinitrosamine: 1174, 2179.

¹⁶See footnote 1, page 10.

DRX (Depth Bomb Explosive)

Composition:	Molecular Weight:	83
Annonium Hitrate 21	Oxygen Belance:	
RIX 21	CO ₂ %	-46 -26
	Deneity: gm/cc Cast	1.68
TMT 40		1.00
Aluminum 18	Melting Point: *C	
C/H Retio	Freezing Point: "C	
Impact Sandhivity, 2 Kg Wt:	Soiling Point: *C	
Bureau of Mines Apparatus, cm 35 Sample Wt 20 mg	Refrective Index, no	
Picatinny Arsenal Apparatus, in. 13	nºs	
Sample Wt, mg 14	ng.	
Friction Pondulum Test:		
Steel Shoe	Vocuum Stebility Test:	
Fiber Shoe	cc/40 Hrs, at 90°C	
	100°C	
Riffe Bullet Impact Test: Trigls	120°C	6.15
% Evales:	135°C	- · - /
Explosions Portiols	150°C	
Burned		
Unaffected	200 Grem Bomb Sand Test:	50 5
	Sand, gm	58.5
Explosion Temperature: 'C	Sunsitivity to Initiation:	
Seconds, 0.1. (no cop used)	Minimum Detonating Charge, gr	ř.
5 Ignites 400	Mercury Fulminate	0.00
10	Leod Azide	0.20
15	Tetryl	0.10
20	Ballistic Morter, % TNT: (a)	146
TESC International Mass Total	Trouzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plote Dent Test: (b)	
	Method	В
100°C Heat Test:	Condition	Cast
% Loss, 1st 48 Hrs	Confined	No
% Loss, 2nd 48 Hrs	Density, gm/cc	1.76
Explosion in 100 Hrs	Brisance, % TNT	102
	Detenation Rate: (c)	
Hommobility Indox.	Confinement	None
Flammability Index:	Can distant	Cont
Flommebility Index:	Condition	Cast
	Condition Charge Diameter, in. Density, gm/cc	Cast 1.6 1.65

DBX (Depth Bomb Explosive)

Becater Sensitivity Test: Condition	(e) Cast	Decempesition Equation: Oxygen, atoms/sec
Tetryl, gm	100	(Z/sec)
Wax, In. for 50% Detonation	1.35	Heat, kilocalorie/mole
	1-37	(ΔH, kcal/mol) Temperature Range, °C
Wax, gm	1.76	
Density, gm/cc	T+ (Q	Phase
Heat of: Combustion, col/gm	(d)	Armor Plate Impact Test:
Explosion, cal/gm	1700	60 mm Morter Projectile:
Gos Volume, cc/gm		50% Inert, Velocity, ft/sec
Formation, cal/gm		Aluminum Fineness
Fusion, cal/gm		
		500-lb General Purpos:
Specific Heat: col/gm/*C	(d)	N. s. W. St tooks
-5°C, density 1.75 gm/cc	0.25	Plate Thickness, inches
		1
		11/4
		11/4
		134
Burning Rate:		
cm/sec		Bond Drop Test:
Thermal Conductivity: col/sec/cm/°C Density 1.75 gm/cc	13.2 × 10 ⁻¹	T7, 2000-16 Sami-Armor-Piercing Bomb vs Concrete:
		Max Safe Drop, ft
Coefficient of Expansion: Linear, %/°C -73°-75°C	4.5 x 10 ⁻⁵	500-16 General Purpose Bomb vs Concrete:
Volume, %/°C		Height, ft
		Trials
Hardness, Mahs' Scale:		Unaffected
		Lity Order
Young's Modulus:	(á)	High Order
E', dynes/cm²	10.4 x 10.10	
E, Ib/inch²	1.51 × 10 ⁶	1000-lb General Purpose Bomb vs Concrete:
Dencity, gm/cc	1.72	
		Height, ft
Compressive Strength: Ib/inch² (d)	3210-3380	Triais
Density 1.78 gm/cc		Unaffected
Vapor Pressure:		Low Order
*C mm Mercury		High Order

DBX (Depth Bomb Explosive)

Fregmentation Test:	Sheped Charge Effectiveness, TNT = 100:		= 100:
90 mm HE, M71 Projectile, Let WC-91:		Glass Cones Ste	el Cones
Density, gm/cc		Hole Vatume	
Charge Wt, Ib		Hole Depth	
Total No. of Fragments:		Celer:	Gray
For TNT			ozuj
For Subject HE		Principal Uses:	Depth charge
3 inch HE, M42A1 Projectile,	Let KC-5:	·	
Density, gm/cc		·	
Charge Wt, Ib			
Total No. of Fragments:		Method of Looding:	Cast
For TNT		Ī	
For Subject HE		Leeding Density: gm/cc	1.61-1.69
Fragment Velocity: ft/sec			
At 9 ft At 251/4 ft		Sterege:	
Density, gm/cc		Method	Dry
Blast (Relative to TNT):	(d)	Hazard Class (Quantity-Distance)	Class 9
Air:		Compatibility Group	Group I
Peak Pressure	118		
Impulse	127	Exudation	
Ener _{.T} y	138		
Air, Confined:		Preparation:	
Impulse		DBX can be manufactured by	slowly adding
Under Weter:		water-wet RDX to molten TNT	
Peak Pressure		jacketed kettle equipped with all the water has evaporated	
Impulse		is added and with heating and	stirring con-
Energy	136	tinued, grained aluminum is a ture is cooled with stirring	continued to
Underground: Peck Pressure		maintain uniformity and when ing the mixture is cast. DB	(can also be mad
Impulse		by adding 21% ammonium nitrations to 42% cyclotol or Compos	sition B of 50/50
Energy		PDX/TNT content plus 1% of the melted at about 100 C.	INT previously
•			

DBX (Depth Bomb Explosive)

Origin:

DBX was developed and used by the United States and Great Britain during World War II. References: 17

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
 - (b) D. P. MacDougall, <u>Kethods of Physical Testing</u>, OSRD Report No. 803, 11 August 1942.
- (c) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.
- M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1346.
- (d) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, MAVORD Report No. 87-46, 26 July 1946.
- (e) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
 - (f) Also see the following Picatinny Arsenal Technical Reports on DEX: 1585 and 1635.

¹⁷See footnote 1, page 10.

1,3-Dismino-2,4,6-Trinitrobensene (DATMB)

Composition:		Melecular Weight: (C6H5N5O6)		243
C 29.6	NO ₂	Oxygen Belence: CO ₃ % CO %		
н 2.1	NH ₂	Deneity: gm/cc	Crystal	1.83
	40 ⁵	Melting Point: *C	(a)	290
C/H Ratio 0.380		Freezing Point: *C		
Impact Sonskivity, 2 Kg Wt:		Beiling Paint: *C		
Bureau of Mines Apparatus, cm Sample Wt 20 mg		Refrective Index, no		
Picatinny Arsenal Apparatus, in				
Sample Wt, mg	9	n _{ii}		
,		n _m		
Friction Pendulum Test:		Vocuum Stability Test:		
Steel Shoe		cc/40 Hrs, at		
Fiber Shoe		90°C		
Rifle Buflet Impact Test: Triols	,	100°C		
. %		135°C		
Explosions		150°C		
Partials		130 C		
Burned		200 Grem Bomb Send Test:		
Unaffected		Sand, gm		46.6
Explosion Temperature:	3	Sensitivity to Initiation:		
Seconds, C.1 (no cop used)		Minimum Detonating Charg	ge, gm	
<u>1</u>		Mercury Fulminate		
5		Lead Azide		0.20
10		Tetryi		0.10
15		Bellistic Morter, % TNT:		100
20		Treuxi Test, % TNT:		
75°C International Heat Test:				
% Loss in 48 Hrs		Plate Deat Test: Method		
10010 Maria Tara		Condition		
100°C Heet Test:	0.00	Confined		
% Loss, 1st 48 Hrs	0.00 0.4	Density, gm/cc		
% Loss, 2nd 48 Hrs		Brisance, % TNT		
Explosion in 100 Hrs	None			
Flammability Index:		Confinement		None
		— Condition		Pressed
Hygroscopicity: %		Charge Diameter, in.		0.5
		Density, gm/cc		1.55
		, Density, gm/cc		2.00

1 3-Dismino-2,4,6-Tri: trobenzene (DATNB)

At 25½ ft Density, gm/cc Method Hazard Class (Quantity-Distance) Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure	0 :
For TNT For Subject HE 3 Inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib Total Me, of Fragments: For TNT For Subject HE Leeding Density: gm/cc At 25½ ft Density, gm/cc Method Hazard Class (Quantity-Distance) Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure	ones
3 Inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE Leading Density: gm/cc At 9 ft At 25½ ft Density, gm/cc Method Itset (Relevive to TNT): Ale: Peak Pressure Impulse Energy Air, Cenfined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure	Yellow
Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE Loading Density: gm/cc At 50,000 psi At 25½ ft Density, gm/cc Method Hazard Class (Quantity-Distance) Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Under gressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure	
Total No. of Fragments: For TNT For Subject HE Leading Density: gm/cc At 50,000 psi Storage: Method Storage: Method Method Storage: Method Me	
Loading Density: gm/cc At 50,000 psi At 50,000 psi Storage: Method Hazard Class (Quantity-Distance) Air: Peak Pressure Impulse Energy Air, Confined: Impulse Imp	Pressed
At 9 ft At 25½ ft Density, gm/cc Method Method Method Method Method Method Method Method Compatibility Group Peak Pressure Impulse Energy Air, Confined: Impulse Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Method Method Compatibility Group Exudation Cook-Off Temperature: Time, minutes Heat of: Explosion, cal/gm	1.65
Method Hazard Class (Quantity-Distance) Air: Peak Pressure Impulse Energy Air, Confined: Impulse Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Underground: Peak Pressure	
Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Weter: Peak Pressure Impulse Underground: Peak Pressure Impulse Underground: Peak Pressure Impulse Energy Cook-Off Temperature: C Time, minutes Heat of: Explosion, cal/gm	Dry
Peak Pressure Impulse Energy Air, Confined: Impulse Cook-Off Temperature: OC Time, minutes Heat of: Explosion, cal/gm Cook-Off Temperature: OC Time, minutes Heat of: Explosion, cal/gm Underground: Fack Pressure	
Energy Air, Confined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure	
Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure	None
Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure	320 8
Energy Underground: Paok Pressure	2876
Underground: Paok Pressure	
Peak Pressure	
Impulse Energy	

Preparation:

Fifty grams (50 gm) of dry styphnic acid was added to 200 gm of anhydrous pyridine with stirring. The resulting slurry was stirred for an additional 30 minutes. The yellow product, dipyridinium styphnate, was collected by filtration and washed with approximately 100 milliliters of diethyl ether. The product was dried over phosphorus (Y) oxide, at room temperature, for 5 hours. Yield of 77 gm (94%), melting point 168° to 170°C (literature melting point 173°C).

To 50 milliliters of phosphorus oxytrichloride, 29.8 gm of the dipyridinium styphnate were added in small portions, with stirring. The reaction mixture was then warmed on a steam bath for 15 minutes. This solution was quenched in 500 gm of ice water. The light yellow precipitate was separated by filtration and washed with water until the washing was neutral to litmus. Yield of 1,3-dichloro-2,4,6-trinitrobenzene 20.4 gm (98%), MP 130 to 131°C (literature MP 128°C).

A suspension of 3 gm of 1,3-dichloro-2,4,6-trinitrobenzene in 9 milliliters of absolute methanol was prepared. This slurry was cooled to 0°C, and dry ammonia was bubbled into the stirred suspension. After 20 minutes the reaction mixture was allowed to warm to room temperature, filtered by suction and washed with methanol and ether until a negative Beilstein test for chloride ion was obtained on the washings. Yield of 1,3-diamino-2,4,6-trinitrobenzene 2.5 gm (7%), MP 288° to 290°C (literature MP 285°C).

Origin:

DATMB, also called 2,4,6-trinitro-1,3-diam.no-benzol or 2,4,6-trinitro-phenylenediamine-(1,3), was first obtained by Noelting and Collin in 1884 (Ber 17, 260) and also by Berr in 1888 (Ber 21, 1546) from 2,4,6-trinitroresorcin dimethylether in contact with ammoniacal alcohol for several days. J. J. Blanksma obtained the same product in 1902 by reacting either 2-chloro-2,4,6-trinitroanisole or 3-chloro-2,4,6-trinitrophenetol with ammoniacal alcohol (Rec trav chim 21, 324) and from 2,4,6-trinitroresorcin methylethyl ether with ammoniacal alcohol (Rec trav chim 27, 56 (1908)).

Meisenheimer and Patzig in 1906 prepared DATMB in the form of yellow needles, MP 280°C from 1,3,5-trinitrobenzene ydroxylamine and sodium methylate in methyl alcohol (Ber 39, 2540). The product was slightly soluble in glacial acetic acid but poorly soluble in other solvents. It decomposed into NH₃ and 2,4,6-trinitroresorcin when boiled with dilute NaOH or KOH (Beil 13,60).

Körner and Contardi prepared DATMB by the reaction of either 2,4-dichloro-1,3,5-trinitro-benzene or 2,4-dibromo-1,2,5-trinitrobenzene with ammoniacal alcohol at room temperature or better by heating to 100°C (Atti R. Accad Lincei (5), 171, 473 (1908)); (5) 18 I, 101 (1909)). A method of preparation by prolonged reaction of N-nitro-N-methyl-2,3,4,6-tetranitroaniline with a saturated ammonia solution was reported in 1913 by van Romburgh and Schopers (Akad Amsterdam Versl 22, 297).

C. F. Van Duin obtained DATNB melting at 301°C by reacting a concentrated aqueous ammonia solution with N-nitro-N,N,N-trimethyl-2,4,6-trinitrophenylenediamine-(1,3) or with N-nitro-N-methyl-N-phenyl-2,4,6-trinitrophenylenediamine-(1,3) (Rec trav chim 38, 89-100 (1919)). Later Van Duin and Van Lennep reacted concentrated aqueous ammonia with 2,4,6-trinitro-3-aminoenisole or 2,4,6-trinitro-3-aminoenhenetol to obtain DATNB melting at 287° to 288°C (Rec trav chim 39, 147-77 (1920)). In 1927 Lorang prepared the same compound by boiling 2,4,6-trinitro-1,3-bis (-nitroethyl ureido) benzene with water or by heating it with ammoniacal alcohol in a tube at 100°C (Rec trav chim 46, 649) (Beil E 17, E II 33).

1,3-Dismino-2,4,6-Trinitrobensene (DATMB)

A recent report describes the preparation of DATHB in two steps from commercially available starting materials. First m-nitroaniline was nitrated with HoSO4-HHO3 acid mixture to tetranitroaniline. The crude tetranitroaniline was converted by methanolic ammonia to disminotrinitro-bensene in a high degree of purity. A conversion of 100 parts of m-nitroaniline into 110 parts of DATHB was obtained by this method, which can easily be carried out on a commercial scale.

Diazodini trophenol

Composition:	N	Melecular Weight: (C6H2N405)	510
c 34.3	4	Oxygen Belencs:	
н 0.9	\wedge	CO ₂ %	-61 -15
N 26.7 02N NO2 02	NO ₂	Density: gm/cc Crystal	1.63
0 38.1	0	Melting Point: *C	157
C/H Ratio 1.056		Freezing Point: 'C	-71
Impact Sensitivity, 2 Kg Wt:		Beiling Peint: 'C	
Bureau of Mines Apparatus, cm Sample Wt 20 mg		Refrective Index, no	
Picatinny Arsenal Apparatus, in.	; (1 lb wt) 7	<u>-</u>	
Sample Wt, mg	15	n _m	
		n 🖁	
Friction Pandulum Test:		Vocuum Stability Test:	
Steel Shoe	Detonates	cc/40 Hrs, at	
Fiber Shoe	Detonates	- 100°C	7.6
Riffle Buillet Impact Test: Trials		120°C	,
%		135°C	
Explosions Partials		150°C	
Portios Burned		100 Green Bouch Sand Toxes	
Unaffected		200 Grem Bemb Send Test: Sond, em	47.5 45.6
		Sand om Black powder fuse	45.6
Explosion Temperature: *C Seconds, 0.1 (no cap used)		Sensitivity to initiation: Minimum Detonating Charge, gm	
1 200	1	Mercury Fulminate	
5 195		Lecd Azide	0.20
10 180)	Tetryl	0.10
15		D. Milata Ada and Al Sales (a)	
20		Bellistic Merter, % TNT: (a)	97
75°C International Host Test:		Trees! Test, % TNT:	
% Loss in 48 Hrs		Plate Dent Test: Method	
100°C Heat Test:		Condition	
% Loss, 1st 48 Hrs	2.10	Confined	
% Loss, 2nd 48 Hrs	2.20	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
		Detenation Rate:	
Floroschiller Indor-		Confinement	
Flammability Index:		Condision Pro	
Flemmebility Index: Hygrescepicity: % 30°C, 90% RH	0.04	Condition Pres Charge Diameter, in.	ssed

*Until it is established which picramic acid (melting point 169°C) isomer is involved (Ref: J Chem Soc, 2082, August 1949).

Diazodinitrophenol

regmentation Test:	Shaped Charge Effectiveness, TNT =	= 100:
90 mm HE, M71 Projectile, Let WC-91:	Glass Cones Steel Cones	
Density, gm/cc	Hole Volume	
Charge Wt, Ib	Hole Depth	
Total No. of Fragments:	Color: ye	
For TNT	10	ellow needles
For Subject HE	Principel Uses: Percussion caps	
3 inch HE, M42A1 Projectile, Let KC-5:		
Density, gm/cc		
Charge Wt, Ib		
Total No. of Fragments:	Method of Looding:	Pressed
For TNT		
For Subject HE	Leading Density: gm/cc Apparer	nt 0.27
regment Velocity: ft/sec	At 3000 pa	i 1.14
At 9 ft		
At 251/2 ft	Storage:	
Density, gm/cc	Method	Under water
-101) Wellioo	Ongel water
lest (Relative to TNT):	Hazard Class (Quantity-Distance)	Class 9
Air:	Compatibility Group	
Peak Pressure		
Impulse	Exudation	None
Energy		
Air, Confined:	Solubility:	
Impulse		
•	Soluble in nitroglycerin, aniline, pyridine, concentra	
Under Weter: Peak Pressure	acid, and in most common ore	
Impulse	Hean of:	
Energy		
	Combustion, cal/gm	3243
Underground:	Explosion, cal/gm Gas Volume, cc/gm	8 20 865
Peak Pressure		•
Impulse	Sensitivity to Electrostation Discharge, Joules:	: (b) 0.012
Energy	Discharge, Joures:	(c) 0.01E
	1	
	1	

Diazodinitro ol

Solubility: gm/100 as of the following substances: (c)

Solubility at 50°C

Sclvent	₹	
Ethyl acetate	2.45	
Methanol	1.25	
Ethanol	2.43	
Ethylenedichloride	0.79	
Carbon tetrachloride	race	
Chloroform	0.11	
Benzene	0.23	
Toluene	0.15	
Petrol: um ether	Insoluble (at 20°C)	
Ethyl ether	0.08 (30°c)	
Carbon disulfile	trace (30°C)	

Preparation: (Chemistry of Powder and Explosives, Davis)

Ten gm of picramic acid is suspended in 120 cc of 5% hydrochloric acid, and under efficient agitation at about 0°C. 3.6 gm sodi: n nitrite in 10 cc water is dumped into the suspension. Stirring is continued for 20 minutes, the product filtered off and washed thoroughly with ice water. The dark brown product, if dissolved in acetone and precipitated in water, turns brilliant yellow.

Origin:

Discovered by Griess in 1858 (Annalen 106, 123; 113, 205 (1800) and studied extensively by L. V. Clark (Ind Eng them 25, 603 (1935). Developed for commercial use in 1928. This compound was patented in the United States by Professor William M. Dane.

Destruction by Chemical Decomposition:

Diazodinitrophenol is decomposed of adding the water-wet material to 100 times its weight of 10% sodium hydroxide. Nitrogen gas is evolved.

- (a) Millip C. Keenan and Dorothy Manas. Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
 - (b) F. W. wow., D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by

¹⁸see footnute :, page 10.

Diszodinitrophenol

Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(c) L. V. Clark, "Diazodinit-ophenol, A Detonating Explosive," Ind Eng Chem 25, 663 (1933).

Seidell, Solubilities of Inorganic and Organic Compounds, Van Nostrand and Co., N. Y.

(d) Also see the following Picatinny Arsenal Technical Reports on Diazodinitrophenol:

0 2 4 5 7 8 9 150 1352 34 355 827 318 2179 610 214 1838

Diethylene Glycol Dinitrate (DEGN) Liquid

Composition: %	Melecular Weight: (C4H8N2O7)	196
C 24.5 $\frac{1}{1}$	Oxygen Belence: CO ₂ % CO %	-4 <u>1</u> - 8
N 14.3 H ₂ C 0	Density: gm/cc Liquid	1.38
-1	Melting Point: °C	2
0 57.1 H ₂ Č ONO ₂ C/H Ratio 0.143	Freezing Point: 'C	·
Impact Sacaltivity, 2 Kg Wt:	Soiling Point: 'C Decomposes	160
Surgou of Mines Apparatus, cm 100+ Sample Wt 20 mg Picatinny Arzenal Apparatus, in. 9 Sample Wt, mg	Cefrective Index, no	1.4498
Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe	Vecuum Stubility Test: cc/40 Hrs, at 90°C	0.3cc/20 hr/g
Riffe Scilet Impact Test: Trials %	120°C	0. 3ee/20 mr/gi
Explosions	150°C	
Portials Burned		
Unaffected -	200 Gram Bomb Send Test: Sand, gm	42.2
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 237	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetry!	
15 20	Ballistic Morter, % TNT:	90
	Treuxi Test, % TNT:	77
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Text: Method	
100°C Heat Test:	Condition	
% Loss, 1st 48 Hrs 4.0	Con Ined	
% Loss, 2nd 48 Hrs 3.0	Denuity, gm/cc	
Explosion in 100 Hrs None	Brisance, % TNT	
Flemmebility Index:	Detonation Rate: Confinement	
Mygroscopicity: %	Condition Charge Diameter, in.	
V-t-attle (-0- / 2:	Density, gm/cc	1.33
Voletility: 60°C; mg/cm ² /hr 193	Rate, meters/second	6760

Diethylene Glycol Dinitrate (DEGN) Liquid

Bosster Sensitivity Test: Condition		Decomposition Equation: Oxygen, atoms/sec
Tetryl, gm	,	(Z/sec)
Wax, in. for 50% Detonation		Heat, kilocolorie/mole (AH, kcal/mol)
Wax, gm		Femperature Ronge, °C
Density, gm/cc		Phase
Meet, of:		
Combustion, cal/gm	2 792	Armor Plate Impact Test:
Explosion, cal/gm	841	40 mm Adams Burlandle
Gas Volume, cc/gm	796	60 mm Morter Projectile: 50% Inert, Velocity, ft/sec
Formation, cal/gm	2020	Aluminum Fineness
Fusion, cal/gm		, value of the second of the s
		500-th General Purpose Bombs:
Specific Heat: cal/gm., 'C		Plate Thickness, inches
		1
		114
		<u>'</u>
		11/2
Burning Rete:		1x4
cm/sec		Bomb Drop Test:
Thermal Conductivity: cal/sec/cm/°C		T7, 2000-lb Semi-Armor-Hieroing Bomb vs Concrete:
Coefficient of Expension:		Max Safe Drop, ft
Linear, %/°C		500-lb General Purpocs Bomb vs Concrete:
Volume, %/°C		Height, ft
		— Tri.
Fierdness, Mohs' Scale:		Unafre_red
		Low Order
Young's Modulus:		High Order
E', dynes/cm²		• • • •
E, Ib/inch² Density, gm/cc		1000-Ib General Purpose Somb vs Concrete:
		— Height, fr
Compressive Strength: Ib/inch ²		Trials
		Unoffected
Vapor Pressure:		Low Order
°C mm Mercury		High Order
20 0.003		, "
0.130		

Diethylene Glycol Dinitrate (DEGN) Liquid

Fragmentation Test:	Shaped Charge Effectiveness, TNT =: 100:		
90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Vc'ume Hole Depth		
Total No. of Fragments: For TNT	Colorless		
For Subject HE 3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: Propellant compositions		
Total No. of Fragments: For TNT For Subject HE	Mathod of Loading:		
Frogment Velocity: ft/sec	Leeding Deasity: gm/cc		
At 9 ft At 25½ ft Density, gm/cc	Storege: Method Liquid		
Blast (Relative to TNT):	Hazard Class (Quentity-Distance) Class 9		
Air: Peok Pressure Impulse Energy	Compatibility Group Exudation		
Air, Confined: Impulse Under Weter: Peak Pressure Impulse	Preparation: DECN can be prepared with approximately 85% yield by adding diethyleneglyco to mixed acid (50% HNC ₃ , 45% H ₂ SO ₄ , and 5% H ₂ O). The temperature is kept at 30°C or lower. The separated DECN is purified by washing with successive portions of water, dilute sodium carbonate solution and water until neutral.		
Energy Underground: Peak Pressure	Hydrolysis, % Acid: 10 days at 22°C		
Impulse Energy	301ubility in Water, gm/100 gm, at: 25°C 0.40 60°C 0.60		
Viscosity, centipolses: Temp, 20°C 8.1	Solubility, gm/100 gm, at 25°C, in: Ether Alcohol 2:1 Ether:Alcohol 00		

Diethylene Glycol Dinitrate (DEGN) Liquid

Origin:

First prepared and studied by Wm. H. Rinkenbach in 1927 (Ind Eng Chem 12, 925 (1927) and later by Rinkenbach and H. A. Asronson (Ind Eng Chem 23, 160 (1931)) both of Picatinny Arsenal. Used in propellant compositions by the Germans during World War II.

<u>lestruction</u> by Chemical Decomposition:

DECH is decomposed by adding it slowly to 10 times its weight of 18% sodium sulfide (Nu2S'9H2O). Heat is liberated by this reaction but this is not hazar lous if stirring is maintained during the addition of DECH and continued until solution is complete.

Reierences: 19

isee the following Picatinny Arsenal Technical Reports on DEGN:

<u>o</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>6</u>	I	2
50 180 620 1490	231 551 1391 1421	72 602 1282 1392	673 1443	494 1624	346 1516 1616 1786	487 1427 1487 1817	279 579 1439

¹⁹See footnote 1, page 10,

Bis(2,2-Dinitropropyl) Fumarate (DNPF)

Composition: %	Melecular Weight: (C ₁₀ H ₁₂ N ₄ O ₁₂)	380	
c 31.6	Oxygen Belence:		
CHCO2CH2C(NO2)2CH2	CO ₂ %	-59	
н 3.2	CO %	-17	
н 3.2 снсо ₂ сн ₂ с(Nо ₂) ₂ сн ₃	Density: gm/cc Crystal	1.60	
0 50.5	Metting Point: °C Form I Form II	89 86	
C/H Ratio	Freezing Point: *C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+	Beiling Peint: °C	-	
Sample Wt 20 mg	Refractive Index, no		
Picatinny Arsenal Apparatus, in. 18 Sample Wt. ma 18	nº		
Sample Wt, mg 18	ពន្ធ		
Friction Pendulum Test:			
Steel Shoe Unaffected	Vecuum Stability Test: cc/40 Hrs, at		
Fiber Shoe Unaffected	90°C		
	'20.C	0.66	
Kifle Bullet Impact Test: Trials	120°C		
%	135°C	0.91	
Explosions	150°C		
Portials			
Burned	200 Grem Bomb Sand Test:		
Unaffected	Sand, gm		
Explosion Temperature: "C	Sensitivity to Initiation:		
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, gm		
1	Mercury Fulminete		
4 Smokes 250	· Lead Azide		
10 15	Tetryl		
20	Ballistic Mortar, % TNT:		
	Trauzi Test, % TNT:		
75°C International Vicet Test: % Loss in 48 Hrs	Plate Dent Test: Method		
2444 Mark Tools	Condition		
100°C Heet Test:	Confined		
% Loss, 1st 48 Hrs	Density, gm, cc		
% Loss, 2nd 48 Hrs	Brisance, % TNT		
Explosion in 100 Hrs	Detenation Rate:		
	Confinement		
Flemmebility Index:	Confinement Condition		
Explosion in 100 Hrs Flammability Index: Hygroscepicity: %	Confinement	1. ևց	

CP 706-177

Bis(2,2-Dinitropropyl) Fumarate (DNPF)

Fregmentation Test:	Shaped Charge Effectiveness, T	NT = 100:
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones	Steel Cones
Density, gm/cc	Hole Volume	
Charge Wt, Ib	Hole Depth	
Total No. of Fragments:		
For TNT	Color:	White
For Subject HE	Principal Uses:	
3 inch HE, M42A1 Projectile, Lot KC-5:	Francipal Usas,	
Density, gm/cc		
Charge V/t, Ib		
Total No. of Fragments:		
For TNT	Method of Looding:	Cast
For Subject HE		
TO Subject the	Looding Density: ym/cc	1.50
regment Velocity: ft/sec		•
At 9 ft At 251/2 ft	Storage:	
Density, gm/cc	300ga:	
Delic ty, griff co	Method	Dry
last (Relative to TNT);	Hazard Class (Quantity-Dista	nce)
A.r:	Compolibility Grc p	
Peak Pressure		
Impulse	Exudation	None
Energy		
Air, Confined:	Heat of:	
Impulse	Combustion, cal/gm	3070 (calculated)
Under Weter:	Detonation, cal/gm	707
Peak Pressure	Viscosity, poises:	(calculated)
Impulse	Temp, 98.9°C	0. 5h6
Energy	106.5°C	0.435
Underground:	Liquid Density, gm/cc:	
Peak Pressure	Тетр, 98.9°С	1.352
Impulse	106.5°C	1.375
Energy	Crisin:	
	Conthesized in 1952 by U.C. Mayet Ordnence Labor Maryland.	

Bis(2,2-Dinitropropyl) Fumarate (DNPF)

Preparation:

(a, b)

fumeryl chloride 2,2-dinitropropenol aluminum bis(dinitropropyl) fumerate chloride

Dinitropropanol was mixed with chloroform (1320 milliliters) and the mixture heated to boiling. The distillate was collected in a water separator. At first the distillate was cloudy and this was dried with calcium chloride before being returned to the system. When no more water was collected in the water separator, the mixture was cooled to room temperature and the separator removed. Fumaryl chloride was introduced, followed by the aluminum chloride which was added in four equal portions. Air was blown into the flask for a minute to effect mixing, and the reaction sustained itself without the addition of heat for one hour. Steam was gradually introduced so that the reflux temperature was reached 2-1/2 hours after the beginning of the reaction. After 3 hours of reflux, the hot liquid was poired into a bucket. As cooling took place the slurry was vigo sly agitated until it finally set up at room temperature. This material was broken up and mixed with dilute ice cold MC1. The solid product was collected on a sintered funnel, washed with water and with heading. The crude material was recrystallized from methanol to give a product melting at 86°C (uncorrected), but after storage for several days the melting point was 89°C.

References: 20

- (e) M. E. Hill. Preparation and Properties of 2,2-Dinitropropanel Esters, NAVORD Report No. 2497, 3 July 1952.
- (b) D. L. Kouba and H. D. McNeil, Jr., Hercules Report on High Explosives. May Contract Nord-11280, Task A, 26 May 1954.

20See footnote 1, page 10.

Bis(2,2-Dinitropropyl) Succinate (DNPS)

Composition:	Molecular Weight: (C ₁₀ ,11,1N,012)	382	
C 31.4	Oxygen Belence: CO ₂ % CO %	-63 -21	
M 14.7 CH2CO2CH2C(NO2)2CH3	Density: gm/cc Crystal	1.51	
೦ 50.2 <mark>ರ</mark> ್ವಾಯ್ದದ್ದುರ(೫೦ ₂) ₂ ದಕ್ಕ	Melting Point: *C	86	
C/H Ratio 0.250	Frenzing Point: *C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparetus cm	Boiling Point: *C		
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Refrective Index, no		
Friction Fendulura Test: Steel Shoe Fiber Shoe	Vecuus. Stability Test: cc/40 Hrs, at 90°C		
Riffe Bullet Propert Test: Trials Keplosions Partials	- 1,00°C 120°C 135°C 150°C	0.10	
Burned Unoffected	200 Grem Bomb Sond Test: Sand, gm		
Explosion Temperature: "C	Sensitivity to Initiation: Minimum Detanating Charge, gm Mercury Fulminate Lead Azide Tetryl Bellistic Morter, % TNT:		
	Trouzi Test, % TNT:		
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method		
100°C Heat Test: % Loss, 1st 48 tirs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Condition Confined Density, gm/cc Brisonce, % TNT		
Flummability Index:	- Detenation Rate: Confinement		
Hygrascopicity: %	- Condition Charge Diameter, in.		
Volatility:	Density, gm/cc Rate, meters/second		

Bis(2,2-Dinitropropyl) Succinate (DNPS)

Fragmentation Test:	Shepod Charge Effactiveness, TNT = 100:
90 mm EE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib	Gloss Cones Steel Cones Hole Volume Hole Depth
Total No. of Fragments: For TNT	Color: White
For Subject HE 3 inch HE, M42A3 Projectile, Let KC-5: Density, gm/cc Charge Wt, ib	Principal Uses:
Total No. of Fragments: For TNT For Subject HE	Method of Loading: Cast
Fregment Velocity: ft/sec At 9 ft	Loading Density: gm/cc
At 251/2 ft Density, gm/cc	Sterage: Method Dry
Bleet (Roletive to TNT): Air:	Hazard Class (Quantity-Distance) Compatibility Group
Peak Pressure Impulse Energy	Exudotion None
Air, Cenfined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Origin: Synthesized in 1953 by M. E. Hill of the U.S. Naval Ordnance Laboratory, White Oak, Maryland.

Bis(2,2-Dinitropropyl) Succinate (DNPS)

Preparation:

(a)

2CH₃C(NO₂)₂CH₂OH + CH₂COC1 AlCl₃ CH₂COOCH₂C(NO₂)₂CH₃ + CHCl

CH₂COOCH₂C(NO₂)₂CH₃ + CHCl

chloride chloride bis(2,2-dinitropropyl) succinate

A methylene chloride solution of dinitropropanol (0.02 mol in 15 milliliters) was mixed with 0.01 mol of succinyl chloride. To this solution 0.003 mol of crushed anhydrous aluminum chloride was added. It was necessary to cool the reaction vessel due to the vigorousness of the reaction. After 25 minutes at room temperature the reaction solution was refluxed 1-1/2 hours. Fine needle-like crystals formed upon cooling and adding hexane. The crystals were slurried in dilute hydrochloric acid and on recrystallization from methanol gave a 93% yield of INPS (melting point 85° to 85.6°C).

References: 21

(a) M. E. Hill, Synthesis of New High Explosives, NAVORD Report No. 2965, 1 April 1953.

²¹Say footnote !, page 10.

2,2-Dinitropropyl-4,4,4-Trinitroputyrate (DNPTB)

Composition: %	Molecular Weight: (C ₇ H ₉ N ₅ O ₁₂)	3 55	
c 23.6	Oxygen Belence:		
-	CO. %	-29 +2.3	
H 2.5 OCH ₂ C(NO ₂) ₂ CH ₃		TE+,)	
N 19-7 C 0	Density: gm/cc Crystal	1.68	
o 54.2 CH2CH2C(NO3)	Melting Point: °C Form I 11 F Form III 59	ore II 95	
C/H Ratio	Freezing Point: *C		
Emport Sensitivity, 2 Kg Wt:	Beiling Point: *C		
Bureau of Mines Apparatus, cm Sample Wt 20 mg	Refrective Index, no		
Picotinny Arsenal Apparatus, in:	ng.		
Sample Wt, mg	"		
	n _s		
Folgton Peridulum Test:	Vocuum Stability Test:	···········	
Studi Shoe	cc/40 Hrs, at		
Fiber Shae	90°C		
Stills Built Impact Test: Tripls	100°C	0.5	
%	120°C		
Explasions	135°C		
Portiols	150°C		
Burned	200 Gram Bamb Sand Test:		
Unoffected	Sand, gm		
Explosion Temperature: °C	Soughtivity to Initiation:		
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, gm		
1 5 300	Mercury Fulminate		
5 300 10	Lead Azide		
15	Tetryl		
20	Ballistic Mortur, % TNT:		
	Truesi Teet, % TRT:		
75°C International Heat Test: % Loss in 49 Hrs	Plate Dent Test:		
	Method		
100°C Heat Test:	Condition		
% Loss, 1st 48 Hrs	Confined		
% Loss; 2nd 48 Hrs	Density, gm/cc		
Explosion in 100 Hrs	Brisance, % TNT		
Phone & Mary In Associate	Detenation Rate:		
Fizamobility Index:	Confinement		
Hygrencepialty: %	Condition		
reygrousopheny: 70	Charge Diometer, in.	٠	
Voistility:	Density, gm/cc	1.67	
· · · · · · · · · · · · · · · · · · ·	Rate, meters/second	7600	

2,2-Dinitropropyl-4,4,4-Trinitrobutyrate (DNPTH)

Fragmentali in Yest:	Shaped Charge Effectiveness, TNT	= 100:		
96 mm HR, MF1 Projectile, Let WG-91:	Gloss Cones Str	nel Cones		
Density, gm/cc	Hole Volume			
Charge Wt, Ib	Hole Depth			
Yetel No. of Progments:	Color:	White		
For YMT	Comm	WILL CO		
For Subject HE	Principal Uses:			
3 lack ME, M42A1 Projectile, Let KC-5:	Village Vest:			
Density, gm/cc	1	. ' '		
Charge Wt, 1b	-			
Ciago Wi, II				
Total Ma, of Fragments:				
For TNT	Method of Loading:	Cast		
For Subject HE	1	,**		
The material of the	Leading Density: grn/cc	1.67		
Fragment Valualty: ft/sec				
At 9 ft				
At 25% ft	Storage:			
Density, gm/cc	Method	Dry		
	Matthod	Dry		
Heat (Relative to THT):	Hazard Class (Quantity-Distance	Hazard Class (Quantity-Distance)		
	Compatibility Comp			
Air: Peak Pressure	Compatibility Group			
hesulae	Exudation	None		
_		Mone		
Energy				
Ale, Confined:	Heat of: (c)	Solvent		
Impulse	Transition, cal/gm CC			
	· ·	2 4.8		
Under Weter:				
Peak Pressure	II	6 -22.0		
Impulse	Heat of Solution, 30°C:			
Energy		olution, cel/gm		
	Material CC.	J. DMF		
Underground: Peck Pressure	Form III 29	5 8.1		
Impulse	Form I 35			
	Form II 19			
Energy	Crigin.			
	Synthesised in 1952 by M. U.S. Naval Ordnance Laborate			
	Maryland.			

2,2-Dinitropropyl-4,4,4-T.initrobutyrate (IRPIB)

Preparation:

(a, b)

 $GR^3C(RO^5)^5OR + ^{RO^5})^3CGS^5GS^5COCT$

Alal3

dinitropropenol

trinitrobutyryl chloride

aluminum chlorida

CHIO 144

 $CH^{2}C(MO^{5})^{5}CH^{5}COCCH^{5}C(MO^{5})^{3}$ + HCI

dinitropropyl trinitrobutyrate

Dinitropropanol, trinitrocutyryl chloride and eluminum chloride were slowly mixed in carbon tetrachloride at 60°C. This mixture was refluxed at 75°C for two hours. After the reaction was completed, the mixture was cooled and the crystalline product separated and purified. Water in the dinitropropanol was removed by assotropic distillation before the acid chloride was added. The purified product had a melting point of 95°C.

Crystallographic Data:

(c)

Three distinct crystallographic modifications of UMPTS have been observed. These polymorphs have been characterized by means of X-ray diffraction and microscopic observation. Form I crystallizes from solution in carbon tetrachloride, chloroform, acetone, chloroform-hamme, sectone-water, or methanol-water at room temperature. Prolonged standing of Form I at room temperature under the mother liquor promotes a transition to Form II. Upon solidification of molten DMPTB, Form II is always observed.

Linear Rate of Transformation of Form II to Form I (c)

Temperature,	Average Rate, sq inch/hour	Standard Deviation	Average Rate, mm/hcur
15	0.347	0.036	0.012
20	0.435	0.025	0.128
25	0.452	0.048	0.133
30	0.475	0.049	0.140
3 5	0.253	0.037	0.6,5

Both Forms I and III gave very erratic sensitivity values. The high temperature polymorph, Form II of DMPTB, gave consistent sensitivity values.

- (a) 3. E. Hill, Preparation and Properties of 2,2-Dinitropropenol Esters, MAYORD Report No. 2497, 3 July 1952.
- (b) W. B. Hewson, Hercule: Report on High Explosives, Mavy Contract MOrd-11280, Task A, 18 October 1954.
- (c) J. R. Holden and J. Wenograd, Physical Properties of an Experimental Castable Explosive 2,2-Dinitropropyl 2,4,4-Trinitrobutyrate DNPTB, MAVORD Report No. 427, 11 December 1956.

²²See footnote 1, page 10.

2,4-Dinitrotoluene (DNT)

Composition: CF 3	Moleculer Weight: (C7HcN2O4)	1.82			
c 46.3	Oxygen Belence: CO ₂ %	-114			
н 3.3	CO %	- 53			
N 15.4	Density: gm/cc	1.521			
Y	Melting Point: *C	71			
0 35•0 NO ₂ C/H Rotio 0•579	Freezing Point: *C				
Impact Sanshivity, 2 Kg Wt:	Beiling Point: "C Decomposes	300			
Bureou ⁴ Mines Apparatus, cm Sample Wt 20 mg	Refrective index, no	`\			
Picatinny Assenal Apparatus, in.	nº.				
Somple Wt, mg	ñ o ñ as				
Friction Pendulum Test:	Vocuum Stability Test				
Steel Shoe Unaffected	cc/40 Hrs, at				
Fiber Shoe Uneffected	90°C				
Riffe Builtet Impact Test: Trials	100°C	0.04			
%	120°C 135°C	••••			
Explosions 0	150°C				
Pcrtials 0	130 €	·			
Burned 0	200 Grem Bomb Sand Tax's				
Unaffected 100	Sond, gm	19.3			
Explosion Temperature: °C	Sensitivity to Initiation:	`			
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, gm				
1	Mercury Fulminate				
5 Decomposes 310	Leod Azide	0.20			
10	Tetryi	0.25			
15 20	Bellistic Merter, % TNT: (a)	71			
	Treuzi Test, % TNT: (b)	64			
75°C International Heat Test: 96 Loss in 48 Hrs	Plate Dent Test: Method				
	Condition				
160°C Heat Test:	Confined				
% Loss, 1st 48 Hrs	Density, gm/cc				
% Loss, 2nd 48 Hrs Explosion in 100 Hrs	Brisonce, % TNT				
Explosion in 100 rms	Detenation Rate:				
Fig wability Index:	Confinement				
	- Condition				
Hygrescepicity: % 25°C, 100% P.H 0.00	Charge Diameter, in.				
	Density, gm/cc				
Volatility:	Rate, meters/second				

2,4- initrotoluene (DNT)

Progmontation Test:	Shoped Charge Effectiveness, TNT = 100:	
90 mm HE, M71 Projectile, Let WC-91:	Glass Cones Steel Cones	
Density, gm/cc	Hole Volume	
Charge Wt, ib	Hole Depth	
Total No. of Fragments:	Cofer: Yellow	
For TNT	161108	
For Subject HE	Detector of them.	
S look MS AASSAS Bustonelle Las MS S.	Principal Uses: Ingredient of propel powder, dynamites an	
3 Inch HE, M42A1 Projectile, Let KC-5:	plastic explosives	_
Density, gm/cc Charge Wt, ib		
Charge Wt, to		
Total No. of Fragments:	Mark And Local Control Control	
For TNT	Method of Leading: Pressed, extruded composition	or cast
For Subject HE		
	Leading Density: gm/cc Year	ieble
Fragment Velocity: ft/sec		
At 9 ft	•	
At 251/4 ft	Storage:	
Density, gm/cc	Method Dr:	,
Heat (Relative to TNY):	Hazard Class (Quantity-Distance) (1)	nes 12
Alm	Compatibility Group Gar	oup D
Peak Pressure	× .	
Impulse	Exudation	
Energy.		
Air, Confined:	65.5°C KI Test:	
Impulse		
	Minutes 60	•
Under Weter: Pack Pressure	Heat of:	
Impulse	Combustion, cml/gm (b) 15	.6
Energy	(0) 134	• •
	Thermal C .ductivity:	
Undergreund:	cal, sec/cm/°C	
Per Pressure	Density 1.322 gm/cc 6.28	x 10 ⁻⁴
Imp. alse	1	
Energy	}	

2,4-Dinitrotoluene (DNT)

Preparation:

See THT.

Solubility: gm/100 gm of the following substances:

Bunyl Alcohol		Mitro	Water		
°c	ź	<u>°c</u>	2	<u>ိင</u>	ź
25 35 45 55 60	0.16 0.29 0.49 0.77 1.03	20	30	22 50 100	0.027 0.037 0.254

301ubility at 15°C, in:

Solvent	ź	Solvent	ž
CHCH CARC TOLUGI CHCOH CHC CHC	65.076 2.431 60.644 45.470 5.014 1.916	CH_COH (absolute) Ether (absolute) Acetone Ethyl acetate CS2 Pyridine	3.039 7.422 82.931 57.929 2.306 76.810

Origin:

Occurs as 75% of the products obtained on the nitration of toluene, the remaining 25% being mainly 2,6-DHT and other isomers of DHT. Also occurs as an impurity in crude THT obtained by standard manufacturing process. used in explosive mixtures at least since 1931.

- (a) L. C. Smith and E. G. Ryster, Physical Testing of Emplosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, ORD Report No. 5746, 27 December 1945.
- (b) A. H. Blatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.
 - (c) Report AC-2861.
 - (d) Also see the following Picatinny Arsenal Technical Reports on DKT:

<u>o</u>	1	2	3	<u>4</u>	2	<u>6</u> ,	I	<u>8</u>	2
810 18 30	1351 1501 1651 1781 1821 2031 2221	72 372 922 1142 1672 1692	43 233 343 673 1023 1663 1743 2013	394 804 1044 1084 1164 1324 1464 1524 1674 1751	1615 2125	186 1556 1816 1896	97 817 837	768 938 1538	69 149 249 279 779 1749

²³See footnote 1, page 10.

Dipentaerythritol Hemmitrate (DPEHN)

Onygen Belence: CO ₂ % CO %	-26
	-20 - 3
Benuity: gm/cc Crystal	1.63
Melting Point: *C	73-7
Freesing Point: *C	
Boiling Point: 'C	
Refrestive Index, ng	
1	
90°C	•
— 100°C	3.7
120°C	11+
135°C	
150°C	
200 Grem Bomb Sand Test:	
Sand, gm	57.4
Sessitivity to initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
Bellistic Merter, % TNT: (a)	142
Truck Test, % THT: (b)	128
Plate Beat Test: Method	
Condition	
Confinement (c)	Copper tube
Condition Charge Diameter, in.	Pressed
Density, gm/cc	1.59 7410
	Preceing Point: "C Belling Point: "C Refrective Index, non non non non non non non non non no

Mipentaerythritol Hexanitrate (DPEHN)

Fragmentation Test:	Shoped Charge Effectiveness, TNT = 100:			
90 mm HE, M71 Projectile, Let WC-91:	Gloss Cones	Steel Cones		
Density, gm/cc	Hole Volume		1	
Charge Wt, ib	Hole Depth			
Total No. of Fragments:	Color:	White	ł	
For TNT		with CG		
For Subject HE	Principal Uses: Ingredies	at of priming	1	
3 lack HE, M42A1 Projectile, Let KG-5:	compositi		[
Density, gm/cc			1	
Charge Wt, Ib				
Total No. of Fragments:	Method of Londing:	Pressed	1	
For TNT			ļ	
For Subject HE			}	
	Leading Density: gm/cc		1	
Fragment Velocity: ft/sec At 9 ft	At 3000 to 4000 psi	1.59]	
At 251/4 ft	Storoge:			
Density, gm/cc	Method	Dry		
Blast (Relative to TPIT):	Hazard Class (Quantity-Distr	once) Class 9	_	
Air: Peak Pressure	Compatibility Group		1	
Impulse	in-udation			
Energy		······································		
Air, Centiced: Impulse	Preparation: (Chemistry Amplosives, Davis)	of Powder and		
Under Weter:	2(HO-CH ₂) ₄ C Dehydra	time.		
Peak Pressure	(HO-CH ₂) ₃ C-O-C(CH ₂ -O		1	
impulse Energy	(0 ⁵ MO-CH ⁵) ³ C-O-C(CH ⁵	-0m02/3		
Energy		manitrate is procured		
Undergreund:	in the pure stat: (melt fractional cryst: llizat		ļ	
Peak Pressure	from moist acetone.	TON OF STREET	Ì	
Impulse	Ovigin: Formed as an im	purity in the prepa-		
Energy	ration of PETN. Prop by W. Frederick and W (Berichte 63, 2861 (1	erties first described Brün in 1930		
	Heat of:			
	Combustion, cal/gm	2260	1	

Dipentaerythritol Hemanitrate (IPEHR)

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OCRD Report Bo. 5746, 27 December 1945.
 - (b) A. Stettbacher, Me Schiess und Sprengstoffe, Leipsiz, p. 363.
- (c) T. L. Mavis, The Chomistry of Fowder and Explosives, John Wiley and Sons, Inc., New York (1943) pp. 218-253.
- (d) S. Livingston, Characteristics of Emplosives HOK and IPEHN, PATR No. 1561, 6 September 1945.

²⁴See footnote 1, page 10.

Dynamite, Low Velocity, Picatinny Arsenal (LVD

Composition: 99.5/0.5 RDX/1-MA dye* 17.5	Molecular Weight:
%	
TWT 67.8 Tripentaerythrito! 8.6	Oxygen Selence: CO, %
68/32 Vistac No 1/DOS binders**	CO %
Callulose acetate, LH-1 2.0	
*RDX, Class E; 1-MA is 96% pure 1-methylamino- anthraquinone.	Beauty: gm/cc Londing 0.9
**Vistac No 1 is low MW polybutene; DOS is dioctylsebacate.	Meliting Point: 'C
C/H Ratio	Freezing Point: *C
Impact Sensitivity, 2 Kg Wt: Burgou of Mines Apparatus, cm	Belling Peint: 'C
Sample Wt 20 mg	Refractive Indea, no
Picatinny Arsenal Apparatus, in. 22	n ₂
Sample Wt, mg 19	n _m
Friction Pondulum Test:	Vo:sum Stability Test:
Steel Shoe Unaffected	cc/40 Hrs, at
Fiber Shoe Unaffected	90°C
	- 100°C
Riffle Bullet Impact Test: Tricks	120°C 0.90
%	135°C
Explosions	150°C
Portiols	
Burned	200 Grein Bomb Sond Tost:
Unaffected	Sand, gm 40.5
Explosion Temperature: "C	Sanithirty to initiation:
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, gm
1	Mercury Fulminate
5 Ignites 480	Lead Azide 0-20
10	Tetryl 0.15
15	Builtistic Conton, % (AT: 00
20	Trough Test, No. 73: 7: 92
75°C International Heat Test:	Plate Boot Test.
% Loss in 48 Hrs	Method
100°C Heat Test:	Condition
% Loss, 1st 48 Hrs	Confined
% Loss, 2nd 48 Hrs	Density, gm/cc
Explosion in 100 Hrs	Brisance, % TNT
	Detraction Rate:
Flammability Index:	Confinement None
	Condition Hard tamped
Hygrescapicity: % 0.31	Charge Diameter, in. 1.25
71°C. 95% RH. 30 days Satisfactory	Density, gm/cc 0.9
Veletility:	Rate, meters/second 4577; or 14400 ft/sec

Dynamite, Low Velocity, Picatinny Arsenal (LVD)

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M73 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib	Glass Conus Steel Cones Hole Volume Hole Depth
Total No. of Fragments: For TNT	Color: Pink
For Subject HE 3 inch NG, M4PAQ Projectile, Let KG-S: Density, gm/cc Charge Wt, Ib	Pulnciped Uses: Excavation, demolition, and cratering
Votel Ma, of Fragments: For TNT For Subject HE	Method of Looding: Hall Packer machine looded
Frequent Velocity: ft/sec At 9 ft At 251/2 ft	Leading Density: gm/cc 0.9 Thumped cartridge 1-1/2" diameter, 8" long Storage:
Density, gm/cc Start (Relative to TNT):	Method Dry Hozord Class (Quantity-Distance) Class 9
Air: Peak Pressure Impulse Energy	Compatibility Group Group A Exudation
Air, Confined: Impulse	Sensitivity to Initiation: Stick dry, No. 6 Electric cap Stick dry, Corps of Engineers Stick wet, Corps of Engineers Positive
Under Weter: Peak Pressure Impulse	Air Gap Propagation: Max distance will, inch 2-1/2 min distance will not, inch 3 Stick Water Immersion:
Energy Underground: Peak Pressure Impulse Energy	Weight gein, \$ 9-16 Heat of: Explesion, cal/gm 625 Gas Volume, ce/gm 611 Cold Storage: Plastic to -65°F Low Temperature Usage: -65°F, 1 day, M2 cap crimper Satisfactory

Preparation:

To date this dynamite has been prepared on a laboratory scale, the details of which are classified. It has been shown, however, to be machine loadable on a Hall packing sachine.

Origin:

第15年まままで

Hobel invented the original dynamite in 1866 and gave the name dynamite to mixtures of mitroglycerin and kieselguhr. The strength of a dynamite was indicated by the percentage of M3 in the mixture. Later oxidants and combustibles were substituted for the kieselguhr, and ammonium nitrate and/or nitrostarch replaced the M3, bringing into existence new types of dynamites. World War II military operations required special demolition and crate ing emplosives free from the objectionable characteristics of M3 and many "dynamite substitutes" were developed for specific applications. The subject low velocity dynamite was developed in 1956 by Picatimny Arsen() (Ref a).

- (a) H. W. Veigt, Development of Low-Velocity Military Explosives Equivalent to Commercial Dynamics, PA Technical Report 2374, March 1957.
 - (b) Also see the following Picutimny Arsenal Technical Reports on Dynamites:

<u>o</u>	1	2	<u>4</u>	2	<u>6</u>	I	<u>8</u>	2
1260 1360 1720 1760	1381 1611	782 1531:	864 1464	1285	1416 1436 1506 2056	507 957	848 1828	1819

²⁵See footnote 1, page 10.

Dynamite, Medium Velocity, Hercules (MVD)

Melecular Weight:
Oxygen Selence:
CO. % -51
CO %
Density: gm/cc Londing 1.1
Density: gm/cc Loading 1.1
Malting Peint: *C
Freezing Point: *C
Mitroglycerin Equivalent, \$ 60
Refrective Index, no
I
n <u>s</u>
n _m
Vecuum Stability Test:
cc/40 Hrs, at
90°C
- 100°C 0.80
120°C 0-94
135°C
150°C
200 Gram Bomb Sand Test:
Sand, gm 52.6
Sansitivity to 1 sitiation:
Minimum Detonating Charge, gm
Marcury Fulminate
Lead Azide 0.20
Tetryl 0.10
Ballistic Marter, % TNT: 122
Trouzi Test, % TNT:
Plate Dent Test:
Method
Condition
Confined
Density, gm/cc
Brisc nce, % TNT
L'atomation Rate:
Confinement None
Condition Machine tamped
Charge Diameter, in. 1.50
Density, gm/cc 1.1

AMOD 104.177

Dynamite, Medium Velocity, Herculas (MVD)

Fragmentation Test:	Shoped Charge Effectiveness, TXT = 109:			
90 mm HE, M71 Projectile, Let WC-91:	Glass Cones Steel Cones			
Density, gm/cc	Hole Volume			
Charge Wt, lb	Hole Depth			
Total No. of Fragments:	Color: Buff			
For TNT	Bull			
For Subject HE	Principal Uses: Excavation, demolition, and			
3 inch HE, MAZA1 Projectile, Let KC-5:	cratering			
Density, gm/cc				
Charge Wt, Ib				
Total No. of Fragments:	Method of Leeding: Hall Packer machine loaded			
For TNT .	months of country and			
. For Subject HE				
	Leading Density: gm/cc 1-1			
Fregment Valuality: ft/sec	Cartridge 1-1/2" diameter, 8" long			
At 9 ft				
At 251/4 ft	Storege:			
Density, pin/oc	Method Dry			
Bloot (Relative to TNT):	Hazard Class (Quantity-Distance) CLass 9			
Air: Peak Pressure	Compatibility Group Group A			
	Exudation			
Impulse	·			
Energy	}			
Air, Confined: Impulse	Sensitivity to Initiation: Stick dry, No. 6 Electric cap Positive Stick dry, Corps of Engineers Positive Stick wet, Corps of			
Under Water:	Engineers > 50% Positive			
Peak Pressure	Air Gap Propagation:			
Impulse	Max distance will, inch 1			
Energy	Min distance will not, inch 2-1/2			
•	Quarry Performance: 4 tons rock/ton explosive			
Undergreend: Peck Pressure	Stick Water Immersion:			
Impulse	Weight gain, % 25-27			
Energy	Heat of: Explosion, cal/gm 935 Gcs Volume, cc/gm 945			
	Cold Storage: Plastic to -70°F .			
•	Low Temperature Usage: -65°F, 1 day, M2 cap crimper Satisfactory			

Dynamite, Medium Velocity, Hercules (MVD)

Preparation:

Manufactured on standard dynamite line and packaged on a Hall packing machine. Details of handling materials and techniques of manufacture are classified.

Origin:

Military forces frequently require exceptition, demolition, and cratering operations for which standard high explosives are unsuitable. Commercial blasting explosives, except black powder, are called dynamites although they may contain no nitroglycerin. The subject dynamite substitute was developed in 1952 by the Hercules Powder Company (Ref a).

- (a) W. R. Baldwin, Jr., Blasting Explosives (Dynamite Substitute), Hercules Powder Company Formal Progress Report, RI 2086, 15 August 1952, Army Contract DA-36-034-0RD-110.
- (b) H. W. Voigt, Development of Low-Velocity Military Explosives Equivalent to Commercial Dynamites, PA Technical Report No. 2374, March 1957.

²⁶See footnote 1, page 10.

EC Blank Fire

Composition: %		Melecular Weight: Approximately 503
Witrocellulose, 13.25% N	80	Oxygen Selence:
Barium Mitrate	8	CC ₂ % +5
Potassium Nitrate Starch	8 3	CO % -25
Diphenylamine	0. 75	Density: gm/cc
Aurine	0.25	Melting Point: 'C
C/H Ratio		Freezing Point: *C
Impact Sensitivity, 2 Kg Wt:		Boiling Point: *C
Bureau of Mines Apparatus, cm	19	Palastina Index
Sample Wt 20 mg Picatinny Arsenal Apparatus, in.		Refrective Index, no
Sample Wt, mg	20	n _{as}
		r.º
Friction Pondulum Test:		Yecsum Stebility Test:
Steel Shoe	Snaps	cc/40 Hrs, at
Fiber Shoe		90°C
Rifle Bullet Impact Test: Trials		100°C
· •		120°C
% Explosions		135°C
Partials		150°C
Burned		200 Gram Bamb Sand Test:
Unaffected		Sand, gm 46.8
Explosion Temperature: °C		Sensitivity to Initiation:
Seconds, 0.1 (no cop used)		Minimum Detonating Charge, gm
1		Mercury Fulminate 0-22
5 Decomposes 20	0	Lead Azide
10		
15		Tetryl
20		Ballistic Morter, % TNT:
		Trouzi Test, % TNT:
75°C International Heat Test: % Loss in 48 Hrs	1.8	Plate Dest Test:
A FORE III AG LIIS	1.0	Method
100°C Heat Test:		Condition
% Loss, 1st 48 Hrs	2.0	Confined
% Loss, 2nd 48 Hrs	0.2	Density, gm, fcc
Explosion in 100 Hrs	None	Brisance, % TNT
		Detenation Rate:
Flammability index:		Confinement
		Condition
Hygrescepicity: % 30°C, 90% RH	6.2	Charge Diameter, in.
		Density, gm/cc
Volatility:		Rate, meters/second

EC Blank Fire

Fragmontation Test:	Shaped Charge Effectiveness, Ti-I' = 100:		
90 mm HE, M71 Projectile, Let WC-91:	Glass Concs Steel	Cones	
Density, gm/cc	Hole Volums Hole Depth		
Chorge Wt, Ib			
Total No. of Fragments:	Color:		
For TNT	J		
For Subject HE	Principal Uses: Grenades; caliber .30 blank		
3 inch HE, M42A1 Projectile, Let KC-5:			
Density, gm/cc			
Charge Wt, Ib			
Total No. of Fragments:	Metho' of Looding:	Loose	
For TNT			
For Subject HE	Loading Density: gm/cc	0.40	
Fragment Velocity: ft/sec			
At 9 ft At 251/4 ft	Sierege:		
Density, gm/cc			
	Method	Wet	
Blast (Relative to TNT):	Hazard Class (Quantity-Distance)	Class 0	
Air	Compatibility Group	Group J	
Feak Pressure]		
Impulse	Exudation		
Energy		·	
Air, Conflaed: Impulse	Preparation: EC Blank Fire is a partially colloided propellant manufactured by a cess using either acetone and ethanol or mixture of butyl acetate and benzene to		
Under Weter: Pook Pressure	gelatinize only a part of the lose. The process is control	ne nitrocellu-	
Impulse	the product passes through a		
Energy	and is retained on a No. 50 Origin:	DTCAG.	
Underground:	Invented in 1882 as bulk spe		
Peak Pressure	less) powder by W. F. Reid and	D. Johnson at	
Imputse Energy	the Explosive Company (whence in England (Eritish Patent 619)		
eferences: 27(a) See the following Picatinny	120°C Heat Test:	Winner-	
rsenal Technical Reports on EC Blank Fire: 891		Minutes 150	
D1, 372, 512, 822, 233, 1373, 854, 65, 667, 17, 69, 579 and 1399.	Red Fumes	300+	
LI, UZ, JIZ BANG ADZZ.	Explodes	300+	

²⁷ See footnote 1, page 10.

Composition:	Molecular Weight:	178		
% Haleite (Ethylene Dinitramine) 55	Oxygen Belence:	· · · · · · · · · · · · · · · · · · ·		
Haleite (Ethylene Dinitramine) 55	CO. %	-51 -17		
TNT 45	CO %	-17		
	Density: gm/cc Cast	1.62		
	Melting Point: 'C Eutectic	80		
C/H Rat v	Freezing Point: 'C			
Impost Sensitivity, 2 Kg Wt: Bursou of Mines Apparetus. cm 95	Beiling Point: °C			
Bureau of Mines Apparatus, cm 95 Sample Wt 20 mg	Refrective Index, no			
Picatinny Arsenal Apparatus, in.	02			
Sample Wt, mg 20	62			
Friction Pandulum Test:	<u> </u>			
Steel Shoe Unaffected	Vocuum Stability Test:			
Fiber Shoe Unaffected	cc/40 Hrs, at 90°C			
	- 100°C	1.0		
Rifle Bullet Impact Test: Trials	120°C	11+		
% Explosions 0	135°C			
Partials 0	150°C			
Burned 7	200 Grem Bomb Sand Yest:			
Unaffected 93	Sand, gm	49.4		
Explanica Temperature: * °C	Sensitivity to Initiation:			
Seconds, 0.1 (no cop used): 435	Minimum Detonating Charge, gr	1		
1 248	Mercury Fulminate	0.22*		
5 Decomposes 190	Lead Azide	0.26*		
10 183	*Alternative initiating char			
15 176	Ballistic Mortus, % THT: (a)			
20 168		119		
*Composition Haleite/TNT, 60/40.	Trough Test, % TMT: (b)	120		
75°C International Heat Test: % Loss in 48 Hrs	Plate Deat Yest:	52/48		
	Method	В		
100°C Heat Test:	Condition	Cast		
% Loss, 1st 48 Hrs 0-2	Confined	No		
% Loss, 2nd 48 Hrs 0.1	Density, gm/cc	1.62		
Explosion in 100 Hrs None	Brisance, % TNT	112		
Planet Allen Indon 1971	— Detenation Rate:			
Flammability Index: Will not continue to burn	Confinement	None		
Hygrescovicity: % None	Condition	Cast		
V VIIIV	Charge Diameter, in.	1.0 1.63		
Veletility:	Density, gm/cc	7340		
	Rate, meters/second	1 300		

Ednatol, 55/45

regmentation Test:			Shoped Charge Effectiveness, TNY	= 100 : <u>50/50</u>
98 mm HE, M71 Projectile, Le	4 WC-91:	.	Gloss Cones Str	rel Cones
Density, gm/cc	1.56	1.62	Hole Volume 126	123
Charge Wt, Ib	2.065	2.092	Hole Depth 117	121
Total No. of Fragments:			A.1	37 - 3 3
For TNT	703	703	Color:	Yellow
Fox Subject HE	842	905	Principal Usus: Projectiles,	bombs; special
3 inch HE, MAZAT Projectile, L	at KC-5:		ammunition co	
Density, gm/cc		1.60		
Charge Wt, Ib		0.845		
Total No. of Fragments:			Method of Londing:	<u></u>
For TNT		514		Cast
For Subject HE		536		
			Looding Density: gm/cc 1.65	
regment Velocity: ft/sec		2730		
At 9 ft At 251/2 ft		2430	Storege:	
Density, gm/cc		1.62	Method	Dry
Heat (Relative to TNT):		(d, e)	Hozard Class (Quantity-Distance)	Class 9
Air:			Compatibility Group	Group I
Peak Pressure		108		
Impulse		110	Exudation Does	not exude at 6500
Energy		10 8		
Air, Confined:			Eutectic Temperature, °C:	79. 8
Impulse			gm Haleite/100 gm TNT 79.80C	0.48
			95.0°C	1.12
Under Weter:				
Peak Pressure			Compatibility with Metals:	
Impulse		••	Dry: Brass, aluminum, ste mild steel, mild steel coate	
Energy		113	proof black paint, and mild	steel plated
Underground:			with cadmium or nickel are uper, magnesium, magnesium,	
Peak Pressure			mild steel plated with coppe	
Impulse			slightly affected.	
Energy			Wet: Copper, brass, magne	
Booster Sensitivity Test:		(à)	aluminum alloy, mild steel,	mild steel coated
Condition		Cast	with scid-proof black paint	
Tetryl, gm		100	plated with copper, cadmium,	
Wax, in. for 50% Detone	tion	1.28	are heavily attacked. Alumi affected and stainless steel	
Density, gm/cc		1.62		'n mieriecoen.

Preparation:

Wet Haleite is added slowly to molton TNT heated at about 100° C in a steam jacketed melting kettle equipped with a stirrer. Heating and stirring are continued until all moisture is evaporated. Loading is done by pouring the mixture cooled to 85° C.

Origin:

Mixtures of Haleite (EINA) and TNT, designated Ednatol; were developed at Picatinny Arsenal just prior to World War II.

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Fhilip C. Keenan and Dorothy C. Pipes, Table of Military High Explosives, Second Revision, MAVORD Report No. 87-46, 26 July 1946.
 - (c) D. P. MacDougall, <u>Methods of Physical Testing</u>, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, ROL Meso 10,303, 15 June 1949.
- (e) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (f) Eastern Laboratory, du Pont, <u>Investigation of Cavity Effect</u>, Sec III, Variation of Cavity Effect with Composition, NURC Contract W-672-ORD-5723.
- (g) Eastern Laboratory, du Pont, Investigation of Cavity Effect. Final Report, 18 September 1943, MIRC Contract W-672-ORD-5723.
 - (h) Also see the following Picatinny Arsenal Technical Reports on Ednatol:

<u>o</u>	1	2	. 3	4	2	<u>6</u>	7	<u>8</u>	2
1290 1400 1420 1530	1091 1451 1651	1162 1372 1482	1193 1363 1493	1294 1434	1325 1395 1885	1796	1457 1477 1737 1797	1198 1388 1838	1279 1469

²⁸See footnote 1, page 10.

Ethylene Glycol Di-Trinitrobutyrete (GTNB)

Composition:	Molecular Weight: (C10H12N6O16)	468			
С 25.6 н 2.6	Oxygen Belence: CO ₂ % CO %	-34 O			
и 17.1 (н ² co ² cH ² cH ² c(но ³)	Density: gm/cc Crystal	1.63			
о 54.7 сн ₂ со ₂ сн ₂ сн ₂ с(nо ₃)	Molting Point: *C	,96			
C/H Ratio 0.235	Freezing Point: *C				
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	Boiling Point: "C				
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Refrective Index. no. no.				
Friction Pundulum Yest: Steel Shoe Fiber Shoe	Vectum Stability Test: cc/40 Hrs, at 90°C 100°C				
Riffe Suffer Impact Test: Tricks Keplosions	120°C				
Portiols	150°C				
Burned Unaffected	200 Grem Bemb Send Test: Sand, gm				
Explosion Temperature: *C Seconds, 0.1 (no cap used) 1 5 50% point 230	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl				
15 20	Ballistic Morter, % TNT:				
	Trougi Test, % TNT:				
75°C International Host Test: % Loss in 48 Hrs	Plate Dent Test: Method	-			
100°C Heet Test:	Condition Confined				
% Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs	Density, gm/cc				
Explosion in 100 Hrs	Brisonce, % TNT				
Flommobility Index:	Detenation Rate: Confinement				
Hygrescapicity: %	Condition Charge Diameter, in.				
	Density, gm/cc				

Ethylene Glycol Di-Trinitrobutyrete (GTNB)

Fregmentation Test:	Shaped Charge Effectiveness, TNT = 100:		
90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth		
Total No. of Fragments: For TNT	Color:		
For Subject HE 3 lash HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: Casting medium for HE compour		
Total No. of Fragments: For TNT For Subject HE	Method of Leading: Cast		
Fragment Velocity: ft/sec	Leading Develty: gm/cc 1.60		
At 9 ft At 251/4 ft	Sterege:		
Density, gm/cc	Method Dry		
Blast (Relative to Th(T):	Hazard Class (Quantity-Distance)		
Air: Peak Pressure Impulse Energy	Compatibility Group Exudation None		
Air, Confined: Impulse	Preparation: (a) By the addition of nitroform to ethylene glycol discrylate. As the method of prepa-		
Under Weter: Peak Pressure Impulse	ration often leads to products difficult to purify, a preparation from ethylene glycol and pure trinitrobutyric acid is in process		
Energy	Origin:		
Underground: Peak Pressure Impulse	First synthesized in 1951 by the U.S. Rubber Company, Research and Development General Laboratories, Passaic, New Jersey.		
Energy	Viscosity, poises:		
	Temp, 98.9°C 0.246 106.5°C 0.193		
	Liquid Density, gm/cc: Temp, 98.9°C 1.467 106.5°C 1.459		

Ethylene Glycol Di-Trinitrobutyrate (GTNB)

- (a) U. S. Rubber Company Progress Report No. 14, Navy Contract Nord-10129, 1 February 1951 to 1 May 1951.
- (b) U. S. Naval Ordnance Laboratory, Silver Spring, Maryland, Letter from Dr. O. H. Johnson to Commanding Officer, Picatinny Arsenal, 8 April 1955 (ORDBB 471.86/44-3, Registry No. 39815); and MOL Letter from Dr. D. V. Sickman to Commanding Officer, Picatinny Arsenal, 29 November 1955 (ORDBB 471.86/159-1; Serial No. 32894).

²⁹See footnote 1, page 10.

Explosive D (Ammonium Picrate)

Composition:	Molecular Waight: (C6H6N407)	246
% C 29.3 O 用illy	Oxygen Belensus CO ₂ % CO %	-52 -13
H 2.4 02N NO2	Density: gm/cc Crystal	1.72
N 22.7	Melting Point: *C Decomposes	265
0 45.6 C/H Retio 0.317	Freening Point: *C	207
	Beiling Point: *C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm		
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 17	Refrective Index, no ao	1.508
Sample Wt, mg 1.8	po	1.870
	- c _o	1.907
Friction FonAulum Test:	Vector Stability Test:	
Steel Sho Unaffected	cc/40 Hrs, at	
Fiber Shoe Unarrected	— 100.c	0.2
Rifle Bullet Import Test: Trials	120°C	0.4
%	135°C	0.4
Explosions 0	150°C	0.4
Partials 0	150 €	
Burned 30	200 Grem Sumb Send Test:	
Unaffected 70	Sand, gm	39.5
Explosion Temperature: 'C	Sonsitivity to Initiation:	
Seconds, 0.1 (no cop used) 405	Minimum Detonating Charge, gm	
1 367	Mercury Fulminate	
5 Decomposes 318	Leod Azide	0.20
10 314	Tetryl	0.0 6
15 299 20 295	Sellistic Merter, % THT: (a)	99
	Treesi Test, % TNT:	
75°C international Heat Test: % Loss in 48 Hrs	Plate Dont Test:	
	Method	Α
100°C Heat Test:	Condition	Pressed
% Lnss, 1st 48 Hrs 0.1	Confined	Yes
% Loss, 2nd 48 Hrs 0.1	Density, gm/cc	1.50
Explosion in 100 Hrs None	Brisance, % TNT	91
	Detenation Rate:	
Flummobility Index:	Confinement	None
Managements of a good	Condition	Pressed
Hygrescepicity: % 100% RH 0.1	Charge Diameter, in.	1.0
Volatility:	Density, gm/cc	1.55
· • • • • • • • • • • • • • • • • • • •	Rate, meters/second	6850

Explosive D (Ammonium Picreta)

90 non HE, M71 Projection, Let W. Dennity, gm/cc Charge Wt, Ib Tatel No. of Fragments: For TNT For Subject HE 3 Inch HE, M42A1 Projectio, Let (Dennity, gm/cc Charge Wt, Ib Tatel No. of Fragments: For TNT For Subject HE	1.50 1.94 703 649 KC-S: 1.55 0.82	Hole Volume Hole Depth Celer:	Yellow-orange
Charge Wt, Ib Total Ma. of Fragments: For TNT For Subject ME 3 Inch ME, M42A1 Projectile, Let I Density, gm/cc Charge Wt, Ib Total Ma. of Fragments: For TNT For Subject ME	1.94 703 649 KC-S: 1.55 0.82	Color: Principal Uses: AP projecti:	les and bombs
Total No. of Fragments: For TNT For Subject HE 3 Inch HE, M42A1 Projectile, Let i Density, gm/cc Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE	703 649 KC-S: 1.55 0.82	Color: Principal Uses: AP projecti	les and bombs
For TNT For Subject HE 3 Inch HE, M42A1 Projectile, Let I Density, gm/cc Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE	649 KC-5: 1-55 0.82 514	Principal Uses: AP projecti	les and bombs
For Subject HE 3 Inch HE, M42A1 Projectile, Let (Density, gm/cc Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE	649 KC-5: 1-55 0.82 514	Principal Uses: AP projecti	les and bombs
3 Inch HE, M42A1 Projectile, Let (Density, gm/cc Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE	1.55 0.82 514		
Density, gm/cc Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE	1.55 0.82 514		
Density, gm/cc Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE	1.55 0.82 514	Method of Leading:	
Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE	0.82 514	Method of Leading:	
For TNT For Subject HE	• .	Method of Loading:	
For TNT For Subject HE	• .	. Attended of Leading:	
	• .		Pressed
Programme A Market Control	508		
		Leeding Density: gm/cc PS1 :	x 10 ³
regment Velocity: ft/sec		1.33 1.41 1.47 1.4	
At 9 ft At 251/4 ft		Storage:	
Density, gm/cc			
bulling, gray at		Method	Dry
Hest (Relative to TNT):		Hazard Class (Quantity-Distance	class 9
Ain		Compatibility Group	Group I
Frak Pressure		1	
Impulse		toudation	None at 65°C
Energy			
Ale, Confined:		Sensitivity to Electrostat:Discharge, Joules:	ic (d)
Impulse			(~/
Under Weter:		Through 100 Mesh:	
Peak Pressure		Confined Unconfined	6.0 0.025
Impulse			
Energy		Booster Sensitivity Tesu:	(c)
		Condition Tetryl, gm	Pressed 100
Underground:		Wax, in. for 50% Detons	
Peak Pressure		Density, gm/cc	1.54
impules		Heat of:	
Energy		Combustion, cal/gm	2890
		Explosion, cal/gm	800
		Formation, cal/gm	395

Preparation:

Explosive D is manufactured by suspending picric acid in hot water and neutralizing it with gaseous or liquid ammonia. As the picrate is formed, it goes into solution; on cooling, it precipitates. An excess of ammonia leads to formation of the red form of ammonium picrate. This should be avoided. The separated crystals are washed with cold water and dried.

Effect of Storage on Sand Test Values:

Minimum Detonating Charge

Stor Years	ege oc	Fulminate (gm)	Tetryl (gm)	Sand Crushed (gm)
0			0.06	23
3.5	50	0.25		23
ž *	Normal		0.03	23
4 *	Mormal		0.04	23
2 **	50	0.24		23

After 3.5 years at 50°C.
 After 3.5 years at 50°C and 2 years at magazine temperature.

Solubility: gm/100 gm (\$), of: (e)

<u>Vie</u>	ater Alcohol Ethyl Acetat				1 Acetate
°c	£	°c	٠ ٤	<u>°c</u>	1
20 100	1.1 75	0 10 30 50 80	0.515 0.690 1.050 1.890 3.620	0 10 . 30 50 80	0.290 0.300 0.380 0.450 0.560

Origin:

First prepared by Marchand in 1841 and used by Brugere in admixture with potassium nitrate as a propellant in 1869. Used as a high explosive after 1900.

Destruction by Chemical Decomposition:

Explosive D (ammonium picrate) is decomposed by dissolving in 30 times its weight of a solution made from 1 part of sodium sulfide (Na₂S-9H₂O) in 6 parts of water.

References: 30

(e) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

³⁰See footnote 1, page 10.

Explosive D (Ammonium Picrete)

- (b) D. P. MacDougall, Methods of Physical Testing, OGRD Report No. 803, 11 August 1942.
- (c) L. C. Smith and S. R. Welton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, .OL News 10,303, 15 June 1989.
- (d) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.
 - (e) Various sources in the open literature.
 - (f) Also see the following Picatinny Arsenal Technical Reports on Explosive D:

<u>o</u>	<u>1</u>	<u>2</u>	3	4	2	. <u>6</u>	1	<u>8</u>	2
340 870 1383	14k1 35 1	132 582 1172 1352 1372 1492	843	694 704 874 1234 1724	65 425 1585 1655 1725 1885 1895	266 556 796 986 1466 1796	1737 1797	328 838 1838	1 729 1 75 9

Glycerol Monolectate Trinitrate (GLTN) Liquid

Composition:	Meleculer Weight: (C6H9N3O11) 299
H 3.0 CH ² -0-C-CH-CH ³	Oxygen Belence: CO ₂ % -30 CO % 3
N 14.1 CH-ONO2	Density: gm/cc Liquid 1.47
сн ₂ — оно ₂	Molting Point: *C
C/H Ratio 0.180	Freezing Point: *C
Impact Sensitivity, 2 Kg We: Bureau of Mines Apparatus, cm 15 (1 1b vt); 42 Sample Wt 20 mg	Refrective Index, no
Picatinny Arsenal Apparatus, in. Sample Wt, mg	n _m 1.464
Friction Pend in Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vecuum Stability Test: cc/40 Hrs, at 90°C
Rifle Bullet Impact Yest: Triols Explosions Portiols	100°C 5.9 120°C 135°C 150°C
Burned Unoffected	200 Green Bomb Sond Test: Sond, gm 13-1
Explosion Temperature: 'C Seconds, 0.1 (no cap used) 1 5 223 10 15	Secultivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Load Azide Tetryl
20	Bellietic Merter, % TNT:
TRACE And the Address of the Address	Trousi Test, % THT:
75°C International Heat Test: % Loss in 48 Hrs	Plate Deat Test: Method
100°C Heat Test:	Condition Confined
% Loss, 1st 48 Hrs 2.5 % Loss, 2nd 48 Hrs 1.8	Density, gm/cc
Explosion in 100 Hrs None	Brisance, % TNT
Flummability Index:	Detenation Rate: Confinement
Hygreecepicity: %	Condition Charge Diameter, in.
Veletility: 60°C, mg/cm²/hr 28	Density, gm/cc Rate, meters/second

Glycerol Monolactate Trinitrate (GLTN) Liquid

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:	
90 mm HE, M71 Projectile, Let WC-91:	Glass Cones Steel Cones ·	
Density, gm/cc	Hole Volume	
Charge Wt, Ib	Hole Depth	
Total No. of Fragments:	Color:	
For TNT		
For Subject HE	Principal Uses: Gelatinizer for nitrocellul	Lose
3 inch HE, M42A1 Projectile, Let KC-5:		
Density, gm/cc		
Charge Wt, Ib		
Total No. of Fragments: For TNT	Method of Loading:	
For Subject HE	Leeding Density: gm/cc	
Brown and Makashar da Jana		
Fregment Velocity: ft/sec At 9 ft At 25½ ft	Storage:	
Density, gm/cc		
	Method Liquid	
Blast (Relative to TNT):	Hozard Class (Quantity-Distance) Class	9
Air:	Compatibility Group	
Peak Pressure		
Impulse	Exadation	
Energy		
-	Hydrolysis, % Acid:	
Air, Confined:	10 days at 22°C 0.021	
Impulse	6 days at 60°C 0.021	
Under Weter:	Solubility in Water,	
Peak Pressure	gm/100 gm, at:	
Impulse	2:5°c <0.01 (60°c <0.015	
Energy		
No decrease de	Solubility, gm/100 gm, at 25°C, in:	
Underground: Peok Pressure		
Impulse	Ether 2:1 Ether:Alcohol	
Energy	Acetone	
	Heat of:	
	Combustion, cal/gm 2407	
	Community Cal/8m	

Glycerol Monolactate Trinitrate (GLTM) Liquid

Preparation:

Glycerol monolectate (GML) is prepared by heating a glycerol lactic acid mixture containing \$4 excess lactic acid at \$116°C for \$112\$ hours with dry air bubbling through the liquid. The product which contains 0.67% free acid is carefully mixed with 6 parts of \$40/60 HMO3/HgSOh maintained at 20°C, stirred for 1 hour, cooled to 5°C, and poured on ice. It is extracted with ether, water-washed, adjusted to pH 7 by shaking with a sodium bicarbonate solution, and again water-washed three times. It is then dried with calcium chloride, filtered and freed of ether by bubbling with air until minimal loss in weight is obtained. The product has a nitrate-nitrogen content of 13.43% (theoretical 14.1% N). Another batch, prepared from RML obtained from glycerol-lactic acid containing 6.5% excess glycerol, had a nitrate-nitrogen content of 14.30%, corresponding to a mixture containing 5.5% nitroglycerin. It is not considered practicable to prepare the pure GLTN.

Origin:

The preparation of a nitrated ester of lactic acid and glycerol, by nitrating a glyceryl lactate with nitric and sulfuric acids, for use in explosives, was reported in 1931 by Charles Stine and Charles Burke (U. S. Patent 1,792,515).

The preparation of glycerol monolactate by heating glycerol with equimolar proportions of a lactic acid ester of an alcohol boiling below 100°C (ethyl lactate) was patented by Richie H. Locke in 1936 (British Patent 456,525 and U. S. Patent 2,087,980).

Reference: 31

(a) P. F. Macy and A. A. Saffitz, Explosive Plasticizers for Nitrocellulose, rATR No. 1616, 22 July 1946.

³¹See fcoinote 1, page 10.

Glycol Dinitrate (GDN) Liquid

Compasition:	Molecular Weight: (C2H4N2O6)	152			
c 15.8 ONO ₂	Oxygen Belence:				
H 2.6 CH ₂	CO: %	0.0 21			
N 18.4	Bensity: gm/cc Liquid, 25°C	1.48			
0 63.2	Melting Point: "C	-20			
C/H Rotio 0.092	Freezing Point: *C				
Impact Sensitivity, 2 Kg Wt:	Boiling Point: *C				
Bureau of Mines Apparatus, cm 4 (1 1b vt); 56 Sample Wt 20 mg	Refrective Index, no				
Picatinny Arsenal Apparatus, in. Sample Wt, mg	na	1.4452			
	กตุ				
Friction Pendulum Test:	Vacuum Stability Test:				
Steel Shoe	cc/40 Hrs, at 90°C				
Fiber Shoe	100°C				
Rifle Sullet Impect Test: Trials	120°C				
%	135°C				
Explosions	150°C				
Portiols Burned					
Unaffected	200 Gram Bamb Sand Test: Sand, gm				
Explosion Temperatura: "C	Sensitivity to Initiation:				
Seconds, 0.1 (no cop used)	Minimum Detonating Charge, gm				
l 5 Evplodes 257	Mercury Fulminate				
10	Lead Azide				
15	Tetryl				
20	Ballistic Morter, % TNT:				
	Trouzi Test, % TNT:				
75°C International Hoot Test: % Loss in 48 Hrs	Plate Dent Test: Method				
100°C Heet Test:	Condition				
% Loss, 1st 48 Hrs	Confined				
% Loss, 2nd 48 Hrs	Density, gm/cc				
Explosion in 100 Hrs	Brisance, % TNT				
Flommobility Index:	Detonation Rate: Confinement	Glass tube			
	Condition	Liquid			
Hygrescopicity: % 30°C, 90% RH 0.00	Charge Diameter, in.	Liquia 10			
	Density, gm/cc	1.485			
Veletility:	1	7300 and 2050			

Glycol Dinitrate (GDN) Liquid

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:				
90 mm HE, M71 Projectile, Let WC-91:	Glass Cones Steel Cones				
Density, gm/cc	Hole Volume				
Charge Wt, Ib	Hole Depth				
Total No. of Fragments:	Color: Yellow				
For TNT	Color: Yellow				
For Subject HE	Principal Uses: Ingredient of nonfreezing				
3 inch HE, M42A1 Projectile, Let KC-5:	dynamite				
Density, gm/cc					
Charge Wt, Ib					
Total vior of Fragments:	Method of Leading:				
For TNT					
For Subject HE	Leading Density: gm/cc				
Fragment Velocity: ft/sec					
At 9 ft At 251/2 ft	Storage:				
Density, gm/cc	Method Liquid				
Blast (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9				
Ale:	Compatibility Group				
Peck Pressure					
Impulse	Exudation				
Energy					
Air, Confland:	Solubility in 1000 cc Water:				
Impulse	Temp, OC Grams				
	15 6.2				
Under Weter: Peak Pressure	20 6.8 50 9.2				
Impulse	Viscosity, centipoises:				
Energy	Temp, 20°C 4.2				
Underground:	Vanor Pressure:				
Peok Pressure	OC mm Mercury				
Impulse	0.0044				
Energy	20 0.038				
-,	40 0.26 60 1.3				
	60 1.3 80 5.9				
	100 22.0				
	Heat of:				
	Combustion, cal/gm 1764				
	Formation, cal/gm (b) 366				

Preparation:

Glycol dinitrate (ethylene glycol dinitrate, dinitroglycol, nitroglycol, dinitrodimethyleneglycol) may be prepared by nitration of ethylene glycol, HOCH2CH2OH, with a mixed nitric acid in the same apparatus that is used for the preparation of nitroglycerin. The glycol is prepared by synthesis from ethylene, and ethylene chlorohydrin:

$$CH_2 = CH_2 \xrightarrow{\text{HOC1}} \text{HOCH}_2CH_2C1 \xrightarrow{\text{H}_2O} \text{HOCH}_2CH_2OH$$

Origin:

Henry was the first to prepare and identify glycol dinitrate (Ber 3, 529 (1870) and Ann chim phys [4] 27, 243 (1872) but Kekulé had previously nitrated ethylene and obtained an unstable oil which he supposed to be glycol nitrate-nitrate. No immediate practical use was added of glycol dinitrate because glycol itself was relatively rare and expensive at the time. It was 1904 before a patent was granted covering the use of GDN as an explosive (DRP 179,789), but it was seven years later before its actual use as an explosive was recorded (Mém poudr 16 (1911) p. 214). The principal physical properties of GDN were determined or recorded by Rinkenbach (Ref b).

- (a) Ph. Maoum, <u>Mitroglycerin and Mitroglycerin Emplosives</u>, translation, E. M. Symmes, The Williams and Wilkins Company, Baltimore (1928), p. 224.
 - (b) Wm. H. Rinkenbach, "The Properties of Glycol Dinitrate," Ind Eng Chem 18, 1195 (1926).
- (c) Wm. H. Rinkenbach, "Glycol Dinitrate in Dynamite Manufacture," Chem Met Eng, 34, 296 (1927).
- (d) Wm. H. Rinkenbach, Application of the Vacuum Stability Test to Nitroglycerin and Nitroglycerin Explosives, PATR 1624, 27 August 1946.

³²See footnote 1, page 10.

Composition:		Molecular Weight:	93
RDX 45		Oxygen Selence:	
TITT 30		CO ₂ %	-66 -66
Aluminum 20		CO %	- 3 6
D-2 Wax 5		Density: gm/cc Cast	1.74
Calcium Chloride, added 0.5		Melting Point: °C	
C/H Ratio		Freezing Point: *C	
It nect Sensitivity, 2 Kg Wt: Bureou of Mines Apparatus, cm		Boiling Point: 'C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. (c) 14 Sample Wt, mg 18		Refractive Index, no	
Friction Pendulum Test:		Vocuum Stability Test:	
•	ffected	cc/40 Hrs, at	
Fiber Shoe		90°C	0.47
Rifle Bullet Impact Test: Trials (b)			0.41
%		135°C	
Explosions 80		150°C	
Partiols		130 C	
Burned		290 Grem Bomb Sand Test:	
Unaffected 20		Sand, gm	49.5
Explosion Temperature: *C (a) Seconds, 0.1 (no ccp used)		Sensitivity to Initiation: Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5 610(min)	(c)	Lead Azide	0.20
10	• •	Tetry!	0.10
15			
20		Bellistic Morter, % TNT: (d)	135
75°C International Heat Test:		Trouzi Test, % TNT:	
% Loss in 48 Hrs		Plate Dent Test: Method	
IGO'C Heet Test:		Condition	
% Loss, 1st 48 Hrs 0-7	8	Confined	
% Loss, 2nd 48 Hrs 0.0		Density, gm/cc	
Explosion in 100 Hrs Non		Brisance, % TNT	
		Detenation Rate:	(a, b)
Flommability Index:		Confinement	None
Museum de la company of the company	- 0 0	— Condition	Cast
Hygreecepicky: % 30°C, 95% RH, 7 day 71°C, 95% RH, 7 day	s 2.01 s 1.77	Charge Diameter, in.	1.0
Voletility:		Density, gm/cc	1.71
		Rate, meters/second	7191

Beester Sensitivity Test: Candition Tetryl, gm 1Yax, in. fo: 50% Detanation Wax, gm Density, gm/cc		Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, *C. Phase
Neet of: Combustion, cal/gm Explosion, cal/gm	3972 923	Armer Plate Impact Test: 60 mm Mortur Projectile:
Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm 178 ⁰ C (b)	733	50% Inert, Velocity, ft/sec Aluminum Fineness
Fusion, cal/gm 18°C (b) Specific Heat: c, um/°C	10.25 (b)	500-th General Purpose Bembe:
30°C	0.269	Plate Thickness, inches
50°C	0.268	1 11/4 11/4 18/4
Burning Rate: cm/sec	/h\	Bomb Drop Test:
Thermal Conductivity: cal/sec/cm/*C 35°C	(b) -3	T7, 2000-16 Semi-Armor-Piercing Bomb vs Concrete:
Coefficient of Expansion: Linear, Al/Inch 0°C 35°C	40 x 10 ⁻¹ 4 83 x 10 ⁻¹ 4	Max Safe Drop, ft 500-16 General Purpose Bemb vs Concrete:
70°c	131 × 10 ⁻¹	Height, ft Trials
Mardness, Mohs' Scale:		Unaffected Low Order
Yenng's Medulus: E', dynes/cm²	(b) 9.0 x 10 ⁹ 5	High Order
E, lb/inch² Density, gm/cc	1-30 x 10 ⁷ 1-71	1000-16 Goneral Purpose Somb vs Concrete:
Compressive Strength: Ib/inch2	See below	Height, ft Trials Unaffected
Veper Pressure: *C mm Mercury		Low Order High Order
Compressive Strength: lb/inch Density, gm/cc Ultimate deformation, %	1083 1.71 1.32	

90 man HE, M71 Projectile, Let ECS-1-17: Density, gm/cc Chorpe Wt, ib Total Na. of Prognasati: For Composition B 998 For Subject HE 714 For 30/20 Tritona) 616 3 inch HE, MAZA1 Projectile, Let KC-5: Density, gm/cc Chorpe Wt, ib Total Na. of Prognasati: For TNT For Subject hiE Leeding Density: gm/cc At 25½ ft Density, gm/cc Method of Lording: Cast	Fregmentation Test:	(b)	Shaped Charge Effectiveness, TNT = '	100:
Charge Wt, lb Total Na. of Fragmants: For Composition B 998 For Subject HE 714 For 30/20 Tritona). 616 3 inch NE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total Na. of Fragmants: For TNT For Subject NE Leeding Dansity: gm/cc 1.71 Impuse NFOC Pendulum 19.8 Energy Leading Class (Quantity-Distance) Air, Confined: Impulse Lender Velocity: Impulse Leading Class (Quantity-Distance) Exudation None Exudation None Leudor Weter: Peack Pressure Impulse Lender Pessure Impulse Lender Pessure Impulse		-17:		Cones
Tatel No. of Fregments: For Composition B 998 For Subject HE 714 For 30/20 Tritona). 616 3 inch NE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Tatel No. of Fregments: For TNT For Subject NE Leading Dansity: gm/cc 1.71 Inguined Velocity: ff/sec Ar 9 ft At 25½ ft Density, gm/cc Method of Lording: Cast Formula Dansity: gm/cc 1.71 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compositivity Group Group I Peak Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.8 Energy Landor Weter: Peak Pressure Impulse				
For Composition B 998 For Subject HE 714 For 80/20 Tritona). 616 3 inch HE, M02A1 Projectile, Let KC-5: Density, gm/cc Chorge Wt, lb Tetal Ma, of Fregments: For TNT For Subject HE Leading Dansity: gm/cc 1.71 Method of Lerding: Cast Leading Dansity: gm/cc 1.71 Method Dry Method Dry Method Dry Method Dry Ale: 3.25" diameter sphere Peack Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.8 Energy Lader Weter: Peack Pressure Impulse Energy Underground: Peack Pressure Impulse Underground: Peack Pressure Impulse	Charge Wt, Ib		Hole Depth	
For Composition B 998 For Subject HE 714 For 30/20 Tritonal. 616 3 inch HE, MAZA1 Projectile, Let KC-5: Density, gm/cc Charge Wt, lb Tetal No. of Prognesse: For TNT For Subject HE At 2514 ft Density, gm/cc Ale: 3.25" diameter sphere Peok Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.8 Energy Land Peok Pressure Impulse Energy Land Pressure Impulse Energy Land Research Let Masses Principal Uses: HE charge Principal Uses: HE charge	Total No. of Fragments:		Calar:	Grav
For 30/20 Tritona). 616 3 inch HE, MAZAT Projectile, Let KC-5: Density, gm/cc Chorge Wt, lb Tetal Me, of Fragments: For TNT For Subject NE Leeding Density: gm/cc 1.71 Inagment Velocity: ft/sec Ar 9 ft At 25½ ft Density, gm/cc Method Dry Hazard Class (Quantity-Distance) Leeding Density: gm/cc 1.71 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Fook Pressure A psi Catenary 25.¼ Impulse NFOC Pendulum 19.8 Energy Leeding Density: gm/cc 1.71 Storage: Method Dry Leading Density: gm/cc 1.71 Storage: Method None Exudation None Exudation None Exudation None Leading Density: gm/cc 1.71 Storage: Method Dry Leading Density: gm/cc 1.71 Leading Density: gm/cc 1.71 Storage: Method Dry Leading Density: gm/cc 1.71 Storage: Method Dry Leading Density: gm/cc 1.71 Storage: Method of Lending: Cast Leading Density: gm/cc 1.71 Storage: Method Dry Leading Density: gm/cc 1.71 Storage: Method Dry Leading Density: gm/cc 1.71 Storage: Method Dry Leading Density: gm/cc 1.71 Leading Den	For Composition B	99 8	1	0129
Density, gm/cc Charge Wt, lb Tatal Me, of Fragments: For TNT For Subject his Leeding Density: gm/cc 1.71 Ingunent Velocity: ft/sec AP 9 ft At 25½ ft Density, gm/cc Method Dry Method Dry Method Dry Method Dry Method Dry Ale: 3.25" diameter sphere Peak Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.6 Energy Alr, Centined: Impulse Under Water: Peak Pressure Impulse Under Water: Peak Pressure Impulse Underground: Peak Pressure Impulse Underground: Peak Pressure Impulse	For Subject HE For 80/20 Tritonal		Principal Uses:	HE charge
Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE Leading Density: gm/cc 1.71 Inequant Velocity: ft/sec Ar 9 ft At 25½ ft Density, gm/cc Method Dry Method Dry Method Dry Method Dry Method Dry Method Dry Ale: 3.25" diameter sphere Peok Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.8 Energy Ale, Confined: Impulse Under Water: Peok Pressure Impulse Under Water: Peok Pressure Impulse Underground: Peok Pressure Impulse	3 inch HE, MAZAT Projectile, Let KC-5:		•	
Tatel No. of Fragments: For TNT For Subject his Leading Density: gm/cc 1.71 Fragment Velocity: ft/sec Ar 9 ft Ar 25½ ft Density, gm/cc Method Dry Hazord Class (Quantity-Distance) Class 9 Air: 3.25" diameter sphere Peak Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.8 Energy Air, Coefined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Underground: Peak Pressure Impulse	Density, gm/cc		[
For TNT For Subject his Leeding Density: gm/cc 1.71 regulated Velocity: ft/sec Ar 9 ft At 25½ ft Density, gm/cc Method Dry Method Dry Method Dry Maxord Class (Quantity-Distance) Class 9 Air: 3.25" diameter sphere Peak Pressure A psi Catenary 25.4 impulse NFOC Pendulum 19.8 Energy Air, Confined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Impulse	Charge Wt, Ib			
Leeding Density: gm/cc 1.71 regement Velocity: ft/sec At 9 ft At 251/2 ft Density, gm/cc Method Dry Hazord Class (Quantity-Distance) Class 9 Air: 3.25" diameter sphere Peak Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.8 Energy Air, Confined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Underground: Peak Pressure Impulse	•		Method of Londing:	Cast
At 9 ft At 25½ ft Density, gm/cc Method Dry Method D	For Subject HE		Leading Density: gm/cc	1.71
Density, gm/cc Method Dry Hazard Class (Quantity-Distance) Class 9 Air: 3.25" diameter sphere Peak Pressure \(\Delta \) psi Catenary Impulse NFOC Pendulum 19.8 Exudation Energy Air, Centined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Impulse	At 9 ft		- Change	
Method Dry Hazard Class (Quantity-Distance) Class 9 Air: 3.25" diameter sphere Peak Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.8 Exudation None Energy Air, Confined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Impulse			3.000	
Air: 3.25" diameter sphere Peak Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.8 Exudation None Energy Air, Confined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Impulse	Density, grit/cc		Method	Dry
Peak Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.8 Exudation None Energy Air, Confined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse	lieut (Relative to TNT);	(a)	Hazard Class (Quantity-Distance)	člass 9
Impulse NFOC Pendulum 19.8 Exudation None Energy Air, Confined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse	Air: 3.25" diameter sphere		Compatibility Group	Group I
Energy Air, Confined: Irnpulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse	Peck Pressure & psi Catenary	-	_	
Air, Cenfined: Irripulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse	impulse NFOC Pendulum	19.8	Exudation	None
Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse	Energy			
Peak Pressure Impulse Energy Underground: Peak Pressure Impulse				
Underground: Peak Pressure Impulse	•			
Underground: Peak Pressure Impulse	Impulse			
Peak Pressure Impulse	Energy			
Energy	Impulse			
	Energy		1	
				

Effect of Altitude, Charge Diameter and Degree of Confinement on Det mation Velocity*

(B	ef	er	en	ce	e)

	i	One-Inc	h Column	Two-In	ch Column
Explosive	Simulated Altitude, Feet	Confined m/s	Unconfined m/s	Confined m/s	Unconfined m/s
TNT,	Ground	6820	6720	6670	5270
density, gm/cc 1.59	30,000	666u	6930(2)	6610	6760(4)
	60,000	6800	. •	6520	6400(4)
	90,000	6810	6720	6550	6610(1)
Average		6798	6790	6588	6260
в-6,	Ground	7190	7360	7340	6870
density, gm/cc 1.69	. 30,000	7300(2)	7430	7360	7980
<u> </u>	60,000	7280	7490	7550	7010
	90,000	7300(3)	7270	7500	7000
Average		7268	7385	7438	7215

^{*}Confined charge in 1/4" steel tube, AISI 1015 seamless, 1" diameter 18" long, and 2" diameter 7" long. All means were determined from sets of five values unless otherwise indicated by (). A 26 gm tetryl booster was used to initiate each charge.

Average Fragment Velocities at Various Altitudes* (e)

		Sir	mulated Alt	tude, Feet	
Explosive	Charge Diameter, Inches	Ground m/s	30,000 m/s	60,000 m/s	90,000 m/s
TRT,	1	2940	2991	3119	2868
density, gm/cc 1.51	2	3623	4191	5077	4980
н-6,	1	346 1	3405	3467	5563
density, gm/cc 1.71	2	4603	4726	499 8	5288

^{*}Outside diameter 2.54"; inside *tameter 2.04"; length 7".

References:

See HEX-1; HEX-3 reference list.

Haleite (Ethylene Dinitramine) (EDMA)

(In recognition of its development as a military explosive by the late Dr. G. C. ...le of Picatinny Arsenal.)

Composition:	No.	Molecular Weight: (C2H6114C4)	150
	- N _ NO ²	Oxygen Balence: CO ₂ % CO %	-32 -10.5
N 37·3	π	Density: gm/cc Crystal	1.71
0 42.7 н _э с	N NO ^S	Melting Point: "C Decomposes	175+
C/H Ratio 0.066	Н	Freezing Point: "C	
Impact Sensit' by, 2 Kg Wt:	cm 48	Boiling Point: °C	
Bureau of ines Apparatus, Sample Wt 20 mg Picatinny Arsenal Apparatus Sample Wt, mg		Refractive Index, no	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Unaffected Unaffected	Vecuum Stability Test: cc/40 Hrs, at 90°C	
Rifle Bulict Impact Test: Tr	rials	100°C	0.5 1.5
	%	135°C	*• <i>y</i>
	o io	150°C	11+
-	io 10		
_	0	200 Grem Bomb Sand Test: Sand, gm	52.3
Explosion Temperature: Seconds, 0.1 (no cap used) 1 5 Decomposes	°C 265 216 189	Sensitivity to Initiation: Minimum Detonating Charge, gri Mercury Fulminate Lead Azide	0.21 0.13
10	178	Tetryl	••
15	173	Bellistic Morter, % TNT: (a)	100
20	170	Bellistic Morter, % TNT: (a) Trauzi Test, % TNT: (b)	139
75°C Internetional Heat Test: % Loss in 48 Hrs	0.01	Plate Dent Test: (c) Method	Α
150°C First Test:		Condition	Pressed
% Loss, 1st 48 Hrs	0.2	Confined	Yes
% Loss, 2nd 48 Hrs	0.3	Density, gm/cc	1.50
Explosion in 100 Hrs	None	Brisance, % TNT	122
Flon mobility Index:	138	Detonation Rate: Cunfinement	Unconfined
Hygrescepicity: %	0.01	Condition Charge Diameter, in.	Pressed
Voletility:	Ni 1	Density, gm/cc Rate, meters/second	1.49 7570

Haleite (Ethylene Dinitarine) (EDNA)

Booster Sensitivity Test: Condition	(d) P re ssed	Decomposition Equation: (e) Oxygen, atoms/sec 10 ^{12.8} 10	e) 12.1 (f) 1011.1		
Tetryi, grn	100	(Z/sec)			
Wax, in. for 50% Detonation	2.09	Heat, kilocalorie/mole 30+5 37 (AH, kcol/mci)	.3 30.8		
Wax, gm		1	- 144-16k [,]		
Density, gm/cc	1.42	Phase Liquid So	lid Solid		
Hast of:		Armor Plate Impact Test:			
Combustion, cal/gm	2477				
Explosion, cal/çm	1276	60 mm Morter Projectile:			
Gas Volume, cc/gm	90 8	50% Inert, Velocity, ft/sec			
Formation, cal/gm	134	Aluminum Fineness			
Fusion, cal/gr:		500-lb General Purpose Bombs:			
Specific Heat: cal/gm/°C		Plate Thickness, inches			
		·			
		1			
		11/4			
		11/2			
		13 ₄			
Burning Rate: cm/sec					
		Bomb Drop Test:			
Thermal Conductivity: col/sec/crn/*C		17, 2000-16 Semi-Armor-Piercing Bemb vs Concrete:			
Coefficient of Expension:		Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete:			
Linear, %/°C					
Volume, %/°C		Height, ft			
		Trials			
Hardmas, Moha' Scale:		Unaffected			
Yaura'a Madulus		Low Order			
Young's Modulus: E', dynes/cm²		High Order			
E , dynes/cm ² E. Ib/inch ²					
Density, gm/cc		1000-lb General Purpose Bomb vs Conc	rete:		
- charty, gray ac		Height, ft			
Compressive Strength: Ib/inch²		Trials			
		Unaffected			
Vapor Pressure: *C mm Mercury		Low Order			
		High Order			
,		- ngr order			

Haleite (kthylene Dinitramine) (EDKA)

Fregmentation Test:	Shoped Charge Effectiveness, TNT =	100:
90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc 1.61 Charge Wt, ib	Glass Cones Steel Hole Volume Hole Depth	Cones
Total No. of Fragments: For TNT	Color:	White
For Subject HE 3 Inch HE, M42A1 Projectile, Let KC-5: 25/5 Haleite/wax Density, gm/cc 1.56 Charge Wt, Ib	Principal Uson:	Booster
Total No. of Fragments: For TNT 514 For Subject HE 600	Method of Looding:	Pressed
Fragment Velocity: ft/sec At 9 ft At 251/2 ft Density, gm/cc	Leeding Dentity: gm/cc pai x 5 10 12 15 1.28 1.38 1.41 1.44 Storage:	20 1.49 Dry
Start (Relative to TNT): Air: Pouk Pressuro Impulse Energy:	Hazard Class (Quantity-Distance) Compatibility Group Exudation	Class 9
Air, Confined: Impulse		
Under Weter: Peok Tessure Impulse Energy		
Underground: Peak Pressure Impulse		
Energy		

Compatibility with Metals:

<u>Dry</u> - Copper, brass, aluminum, mild steel, stainless steel, mild steel coated with acidproof black paint, and mild steel plated with copper nickel, cadmium or zinc are unaffected. Nagnesium and magnesium-aluminum alloy are slightly affected.

<u>Wet</u> - Copper, brass, mild steel coated with acid-proof black paint, and mild steel plated with copper, cadmium, nickel or zinc are heavily corroded. Aluminum is slightly affected and stainless steel is unaffected.

Impact Sensitivities of Various Crystal Habits:

Bureau of Mines Impact Test; 2 Kg Wt:

Habit	<u>cm</u>
lst plate	55
2nd plate	55
Bi-pyremid	'n
Bracydome	66
Sphenoid	46

Solubility: gm/100 gm (\$) of:

Water		<u>A1</u>	coho?
°c	£	°c	2
20	0.25	20	1.00
40	0.75	40	2.46
60	2.13	60	5.22
80	6. 3 8	78	10.4
100	>20	-	

Preparation:

(Summary Technical Report of the NDRC, Div 8, Vol 1)

$$\begin{array}{c} \operatorname{CH_2O} + \operatorname{HCN} \longrightarrow \operatorname{Ho} \operatorname{CH_2CN} \\ (98\% \ \operatorname{yield}) \\ \operatorname{Ho} \operatorname{CH_2CN} + \operatorname{NH_3} \longrightarrow \operatorname{NH_2CH_2CN} + \operatorname{H_2O} \\ (82\% \ \operatorname{yield}) \\ \operatorname{NH_2CH_2CN} + \operatorname{2H_2} \longrightarrow \operatorname{H_2N} \operatorname{CH_2CH_2NH_2} \\ (88\% \ \operatorname{yield}) \\ \operatorname{CH_2} \longrightarrow \operatorname{NH_2} \\ \operatorname{CH_2} \longrightarrow \operatorname{NH_2} \\ \operatorname{CH_2} \longrightarrow \operatorname{NH_2} \\ \operatorname{CH_2} \longrightarrow \operatorname{NH_2} \\ \end{array}$$

Haleite (Ethylene Dinitramine) (EDNA)

$$\begin{array}{c}
\text{CH}_2 - \text{NH} \\
\text{CH}_2 - \text{NH} - \text{NO}_2 \\
\text{CH}_2 - \text{NH} - \text{NO}_2
\end{array}$$

$$\begin{array}{c}
\text{CH}_2 - \text{N} - \text{NO}_2 \\
\text{CH}_2 - \text{N} - \text{NO}_2
\end{array}$$

$$\begin{array}{c}
\text{CH}_2 - \text{N} - \text{NO}_2 \\
\text{CH}_2 - \text{N} - \text{NO}_2
\end{array}$$

$$\begin{array}{c}
\text{CH}_2 - \text{N} - \text{NO}_2 \\
\text{CH}_2 - \text{N} - \text{NO}_2
\end{array}$$

The raw materials used in this process are cheap and available; the first three reactions proceed smoothly, rapidly and in good yield (70% overall), and only the third requires high pressures. The reaction of ethylenediamine with carbon dioxide at about 220°C and 820 atmospheres has been worked out and is more satisfactory for the preparation of ethyleneurea than the use of chlorethyl carbonate or urea and better than the reaction of acetic anhydride and ethylenediamine to yield N,N'-diacetyl-ethylenediamine which can be treated in a way similar to the above to yield Haleite.

Ethyleneures is very easily nitrated, with strong nitric acid (98%), at ordinary temperature, and in a very short time, and the dinitroethyleneures produced appears to appears, yielding Haleite, immediately after solution in water at 95° C. Both the nitration and hydroly-is are practically quantitative.

Origin:

First described in 1877 by Franchimont and Klotbie (Rec trav chim 7, 17 and 244) but it was 1935 before its value as an explosive was recognized. Standardized during World War II as a military explosive.

Destruction by Chemical Decomposition:

Haleite is decomposed by addition to hot, dilute sulfuric acid. Nitrous oxide, acetaldehyde and othylene glycol are evolved. Haleite is also decomposed by addition to 5 times its weight of 20% sodium hydroxide.

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
 - (t) Report AC-2983/Org Ex 179.
 - (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) R. J. Finkelstein and G. Gemow, <u>Theory of the Detonation Process</u>, NAVORD Report No. 90-46, 20 April 1947.
- (f) M. A. Cook and M. Taylor Abbeg, "Isothermal Decomposition of Explosives." University of Utah, Ind Eng Chem (June 1956) pp. 1090-1095.

³³⁵ee footnote 1, page 10.

Haleite (Ethylene Dinitramine) (EDNA)

Composition:		Melecular Weight:	102
% RDX 40		Oxygen Belence:	,
TNT 38		CO, %	-68
Aluminum 17		CO %	-35
D-2 Wex 5		Density: gm/cc Cast	1.72
Calcium Chloride,		Malting Print: 'C	
added 0.5 C/H Ratio		Freezing Point: *C	
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines /\pparatus, cm Sample Wt 20 mg		Refrective Index, nº	
Picatinny Arsenal Apparatus, in.	16	n _m	
Sample Wt, mg	21	nº	
Friction Pendulum Test: (b)			(a, b)
Steel Shoe	Unsffected	Vecuum Stubility Test: cc/40 Hrs, at	(■, 0)
Fiber Shoe		90°C	
		— 100°C	0.47
Rifle Bullet Impect Test: Trials	(b)	120°C	0.98
% 5		135°C	
Explosions 73		150°C	11+
Partials Burned		200 Green Bomb Send Test:	
Unaffected 28		Sand, gm	48.1
Explosion Temperature: 'C	(a)	Sensitivity to Initiation:	
Seconds, 0.1 (no cop used)		Minimum Detonating Charge, gm	
1		Mersury Fulminate	••••
5 480		Leod Azide	0.20
10		Tetryl	0.10
15 20		Bellistic Morter, % TNT: (d)	133
		Treuzi Test, % TNT:	
75°C Internation at Test: % Loss in 48's and		Plate Dent Test: Method	
100°C Heat Test:	(b)	Condition	
% Loss, 1st 48 Hrs	0.05 8	Confined	
% Loss, 2nd 48 Hrs	0.00	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
		Detenation Rate:	(a, b)
Flommobility Index:		Confinement	None
0-		Condition	Cast
Hygrescepicity: % 30°C, 95% RH, 7.°C, 95% RH,	7 days 2.98 7 days 1.13	Charge Diameter, in.	1.0
	i days 1.13	Density, gm/cc	1.69
Veletility:		-	7224

Posster Sensitivity Test: Condition	(c) Cast	Decomposition Equation: Oxygen, atoms/sec
Tetryl, gm	100	(Z/sec)
Wax, in. for 50% Detanation	1.25	Heat, kilocalorie/mole (AH, kca mol)
Wax, gm		Temperature Range, °C
Density, gm/cc	1.73	Phase
Meet of: Combustion, cal/gm	(b) 3882	Armor Plate Impact Test:
Explosion, cai/gm	91 9	AR Marker Berlandik.
Gas Volume, cc/gm		50 mm Morter Projectile: 50% Inert, Velocity, ft/sec
Formation, cal/gm	758	Aluminum Fineness
Fusion, col/am 78°C	9.25	- Herricians - Francise
		500-lb General Purpose Bamba:
Specific Heat: cal/gm/°C	(b)	
30°C	0.249	Plate Thickness, inches
50 ^o c	0.264	1
,-0	V120-	114
		11/2
		134
cm/sec Thermal Conductivity: cal/sec/cm/°C 35°C	(b) 0.97 x 10 ⁻³	Bomb Drop Test:
cal/sec/cm/°C 35°C	0.97 x 10 3	T7, 2000-16 Semi Armor-Piercing Bomb vs Concrete:
Coefficient of Expansion: Lingar, &LAnch	(b)	Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete:
0°C 35°C	46 x 10-4	Source Control Purpose Some VS Controle:
35°C 70°C	95 × 10 ⁻¹⁴	Height, ft
100	1/7 7 10	Trials
Herdness, Mohs' Scale:		Unaffected
		Low Order
Young's Medulus:	(p)	High Order
E', dynes/cm²	10.3 x 10 ⁹	Tight Growt
E, lb/inch²	1.49 x 10 ⁻⁵	1000-lb General Purpose Bomt vs Concrete:
Density, gm/cc	1.69	
Companying Strength, th /i-ch2	See below	Height, ft
Compressive Strength: Ib/inch ²	Dee Delow	Trials
		Unaffected
Vapor Pressure:		Low Order
*C mm Mercury	(b)	High Order
Compressive Strength: lt/inch2	1303 1.69	
Density, gm/cc		

Fragmuntation Test:	(p)	Shaped Charge Effectiveness, TNT =	90:
90 mm ME, M71 Projectile, Let EGS-1-	-17:	Glass Cones Steel	Cones
Density, gm/cc		Hale Volume	
Charge Wt, Ib		Hole Depth	
Total No. of Fragments:		Celer:	Gray
For Composition B	99 8		(ray
For Subject HE For 80/20 Tritonal	910 616	Principal Uses:	HE charge
3 inch HE, M42A1 Projectile, Let KC-5:			
Density, gm/cc			
Charge Wt, Ib			
Total No. of Fragments: For TNT		Method of Looding:	Cast
For Subject HE		Leading Density: gm/cc	1.69
Fragment Velocity: ft/sec			1.09
At 9 ft At 25½ ft		Storage:	
Density, gm/cc		Method	Dry
liest (Relative to TNT):	(e)	Hozard Class (Quantity-Distance)	Class 9
Air: 3.25" diameter sphere Peak Pressure & psi Catenary	24.7	Compatibility Group	Group I
Impulse NFOC Pendulum	19.6	Exudation	None
Energy	****		· · ·
Air, Confined: Impulse			
Under Weter: Peak Pressure			
Impulse		1	
Energy			
Underground: Peak Pressure			
Impulse		1	
Energy		i	
- ,			
		1	

Composition:		Molecular Weight:	64
RDX 31		Oxygen Belence:	
TNT 29		CO, %	-75
Aluminum 35		CO %	-49
D-2 Wax 5		Density: gm/cc Cast	1.84
Calcium Chloride, added 0.5		Melting Point: 'C	
C/H Ratio		Freezing Peint: *C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm		Boiling Point: *C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	15 23	Refrective Index, no no no	
Friction Pendulum Test:		Vocuum Stability Test:	(a, b)
Steel Shoe	Unaffected	cc/40 Hrs, at	(=, 0,
Fiber Shae		90°C	****
Rifle Bullet Impret Test: Trials	(b)	— 100°C	0.45
	(5)	120°C	
Explosions 78		135°C	
Partials		150°C	
Burned		200 Grem Bomb Sand Test:	(b)
Unaffected 22		Sand, gm	44.9
Explosion Temperature: °C Seconds, 0.1 (no cap used)	(a)	Sensitivity to Initiation: Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5 500)	Lead Azide	0.20
10		Tetryl	0.10
15 20		Ballistic Morter, % TNT: (d)	111
		Troug Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs		Piete Dent Test: Method	
167°C Heat Test:	(b)	Condition	
% Loss, 1st 48 Hrs	0.70	Confined	
% Loss, 2nd 48 Hrs	0.00	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
Flammebility Index:		Detenation Rate: Confinement	(a, b) None
Hye peconicity: % 30°C, 95% RH.	7 days 2.01	— Condition	Cast
Hygroscopicity: % 30°C, 95% RH. (b) 71°C, 95% RH.	7 days 0.31	Charge Diameter, in.	1.0
Voletility:		Density, gm/cc	1.81
v www.ratv:		Rate, meters/second	6917

Bosster Sensitivity Test: Condition		Decemposition Equation: Oxygen, atoms/sec
Tetryl, gm		(Z/sec)
Wax, in. for 50% Detonation		Heat, kilocalorie/mole
Wax, gm		(ΔH, kcol/mol) Temperature Range, °C
Density, gm/cc		Phase
Heat of: Combustion, cal/gm	(b) 14495	Armor Plate Impact Test:
Explosion, cal/gm	877	60 mm Morter Projectile:
Gas Valume, cc/gm		50% Inert, Velocity, ft/sec
Formation, cal/gm	491	Aluminum Fineness
Fusion, cal/gm	9 . 30	
		500-lb General Purpose Bembs:
Specific Hust: cal/gm/*C		
30°c	0.254	Plate Thickness, inches
5 0 ° შ	0.254	1
		134
		11/2
		134
Burning Rate:		
cm/sec		Bomb Drop Test:
Thermel Conductivity: cal/sec/cm/*C 35°C	(b) 1.70 x 10 ⁻³	T7, 2000-lb Semi-Armor-Piercing Semb vs Concrete:
Coefficient of Expension:	(b)	Max Safe Drop, ft
Linear, Al/Inch	40 x 10 ⁻⁴	500-lb General Purpose Bomb vs Concrete:
0°C 35°C	63 x 10 ⁻¹	_
70°C	130 x 10	Height, ft
Mandage Maked Control		Trials
Hardness, Mehe' Scale:		Unaffected
Young's Modulus:	(b)	Low Order
E', dynes/cm²	11.5 x 10 ⁹	High Order
E, Ib/inch²	1.67 x 10 ⁵	1000 th General Promose Possibles Commission
Density, gm/cc	1.81	1000-ib General Purpose Bomb vs Concrete:
		Height, ft
Compressive Strength: Ib/inch ²	See below	Trials
		Unaffected
Vapor Pressure:		Low Order
°C mm Mercury		High Order
	1610	
imm Mercury impressive Strength: 1b/inch ² Density, gm/cc Ultimate deformation. 5	1610 1.61 1.37	

regmentation Test:		Shaped Charge Effectiveness, TNT =	100:
90 mm HE, M71 Projectile, Let EGS-1-	17:	Gloss Cones Steel	Cones
Density, gm/cc		Hole Volume	
Charge Wt, Ib		Hole Depth	
Total No. of Fragments:		Color:	
For Composition B	99 8	Color:	Gra;
For Subject HE For 80/20 Tritonal	476 61 6	Principal Uses:	HE charge
3 inch HE, M42A1 Projectile, Let KC-5:			
Density, gm/cc		J	
Charge Wt, Ib			
Total No. of Fragments:		Method of Leading:	Chat
For TNT For Subject HE			
		Leading Density: gm/cc	1.81
regment Velocity: ft/sec At 9 ft			
At 25½ ft		Storage:	
Density, gm/cc		Method	Dry
est (Relative to TNT):	(a)	Hazard Class (Quantity-Distance)	Class 9
Air: 3.25" diameter sphere Peak Pressure A psi Catenary	25.5	Compatibility Group	Group I
Impulse NFOC Pendulum	20. 6	Exudation	None
Cnergy			
Ale, Confined:	4.		
Impulse	_	1	
Under Weter: Peak Pressure	•		
Impulse		1	
Energy			
Underground: Pook Pressure		1 	
Impulse	:		
Energy			

HBX-1; HBX-3

The Stability of HBX Compositions Made With and Without Desiccants and Containing Added Moisture *

	Moisture,	Acidity,	100°C Vac		Hygrosco	picity, 🖇
Explosive	2	<u> </u>	CC gas	Hours	959	RH
Composition					30°C	71°C
Standard HBX-1	0.73	0.011	0.47	40	+2.98	+1.13
+0.2% moisture	·		0.68	40		
+0.4% moisture	!	•	0.62	40		
+0.6% moiscure	;	<u>!</u> ·	0.50	40		
HBX-1 without CaCl	0.00	0.029	0.36	40	-0.06	-0.25
+0.2% moisture			0.25	40		
+0.4% moisture			0.23	40		
+0.6% moisture		:	0.27	40		
HBX-1 with silica gel	0.06	0.031	0.73	40	+0.08	+0.04
Standard HBX-3	0.54	0.012	0.45	40	+2.01	+0.31
+0.2% moisture	0.,,4	1 0.012	0.47	40		.0.
+0.4% moisture			0.43	40		
+0.6% moisture			0.41	40		
HEX-3 without CaCl	0.02	0.049	0.46	40	-0.06	-0.29
+0.2% moisture			0.26	40		
+0.4% moisture			0.26	40		
+0.6% moisture			0.20	40		
HRX-3 with silica gel	0.04	0.100	0.45	40	+0.09	+0.05
Standard N-6	0.71	0.017	0.47	40	+2.01	+1.77
+0.2% moisture	0.11	0.01	0.88	40	72.01	AT+11
+0.4% moisture			0.63	40		
+0.6% moisture			0.65	40		,
H-6 without CaCl	0.03	0.082	0.10	40	-0.06	-0.25
+0.2% moisture			0.10	40		
+0.4% moisture			ა.25	40		
+0.5% moisture			0.23	40		
H-6 with silics gel	0.05	0.028	0.43	40	+0.09	+0.06

^{*} All samples were ground to 20/100 mesh size, 7 days before tests. Silica gel used was Fisher Mentific Company, Lot 541492, through 100 mesh U. S. Standard Sieve.

HBX-1; HBX-3

Preparation:

HBX explosive mixtures are prepared by melting TNT in a steam-jacketed melt kettle equipped with a mechanical stirrer. Water-wet LDX is added slowly with stirring and heating until all the water is evaporated. Aluminum is added, and the composition is stirred until uniform. D-2 wax and calcium chloride are then added. The desensitizer wax, also known as Composition D-2, consists of 64% paraffin and other waxes, 14% nitrocellulose and 2% legithin. The mixture is cooled from approximately 95° to 100°C to a temperature considered suitable for casting (the lowest practicable pour temperature). HBX can also be made by adding the calculated amount of TWT to Composition B to outsin the desired proportion of RDX/TNT. The appropriate weights of the other ingredients are added to complete the mixture.

Origin:

Developed during World War II, as relatively insensitive mixtures, by adding 5% desensitizer to Toroex II, for high blast explosive applications.

- (a) O. E. Sheffield, Blast Properties of Explosives Containing Aluminum or Other Retal Additives, PATR No. 2353, November 1956.
- (b) S. D. Stein, G. J. Horvat and O. E. Sheffield, Some Properties and Characteristics of HBX-1, HBX-3 and H-6, PATR No. 2431, June 1957.
- (c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo. 10,303, 15 June 1949.
- (d) S. R. Walton, Report on the Program to Develop an Improved HBX-Type Explosive, MAYORD Report No. 1502, 26 July 1950.
- (e) A. W. O'Brien, Jr., C. W. Plummer. R. P. Woodburn and V. Philipchuk, <u>Detonation Velocity Determinations and Fragment Velocity Determinations of Varied Explosive Systems and Conditions</u>, National Northern Corporation Final Summary Report NNC-F-13, February 1958 (Contract DAT-19-020-501-0kD-(P)-58).
- (f) Also see the following Picatinny Arsenal Technical Reports on HBX Explosives: 1756, 2138, 2169.

³⁴See footnote 1, page 10.

HEX-24

Composition:		Molscular Weight:	47.6
% Potassium Perchlorate	32	Oxygen Belence:	١
(17 microns)	1.0	CO: %	-42
Aluminum, atomized (20 microns)	48	CO %	- 34
RDX (through 325 mesh)	16	Presed of 20,000 psi	1.39 2.1
Asphaltum (through 100 mesn)	. . .	Meking Point: °C	<u> </u>
C/H Ratio		Freezing Point: *C	
Impact Sonsitivity, 2 Kg Wt:		Beiling Point: 'C	
Bureau of Mines Apparatus, cm Sample Wt 20 mg		Refrective Index, nº	
Picatinny Arsenal Apparatus, in.	16	nº	
Sample Wt, mg	24		
		n‰	
Friction Pendulum Tust:		Vocuum Stability Test:	
Steel Shoe	Detonates	cc/40 Hrs, at	
Fiber Shoe	Unaff-cted	90°C	
200 B Mark 1 200 B T 1 1		— 100°C	1.25
Rifle Bullet Impact Test: Trials		120°C	
% Explosions		135°C	
Partials		150°C	
Burred		200 Gram Bomb Sand Test:	
Unoffected `		Sand, gm	12.5
Explosion Temperature: °C		Sensitivity to Initiation:	
Seconds, 0.1 1/2 or used)		Minim Detarating Charge, gm	
1 5 520		Mercury Fulminate	
,	•	Lead Azide	0.20
10 15		Tetryl	0.25
20		Ballistic Morter, % TNT:	
		Trouzi Trot, % TNY:	
75°C International Heat Test: 4 Loss in 46 Hrs		Platy Dent Test: Method	
100°C Kee? Test:		Condition	
% Loss, 1st 48 Hrs	0.15	Confined	
% Loss, 1st 46 Firs	0.00	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
Explosion in 100 mis	-	Detenation Rate:	
Flammability Index:		Confinement	
		Condition	
Hygroscopicity: %	None	Charge Diameter, in.	
		Density, gm/cc	
Volatilky:	None	Rate, meters/second	

Frogmentation Test:	Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile, Let WC-91:	Glass Cones Steel Cones
Density, gm/cc	Hole Volume
Charge Wt, io	Hole Depth
Total No. of Fregments:	
For TNT	Color: Gray
For Subject HE	
3 inch HE, M42A1 Projectile, Let XC-5:	Principal Uses: HE filler for small caliber projectiles
	projecuites
Pensity, gm/cc	
Charge Wt, Ib	
Total No. of Fragments:	Method of Leading: Pregsed
For TNT	Trapped.
For Subject HE	
	Leading Density: gm/cc
Fregment Velecity: ft/sec	Pressed at 20,000 psi 2.1
At 9 ft	
At 251/ ₅ ft	Storage:
Density, gm/cc	Method Dry
Heat (Relative to TNT):	Hazard Class (Quantity-Distance)
Aire	Compatibility Group
Peak Pressure	Eu desten
Impulse	Exudation None
Energy	
Air, Confined:	Static Tests:
Impulse	20 mm T215El Projectile: PA Peak Pressure, psi 55
·	PA Peak Pressure, psi 55 NFOC 20" Blast Cube 44
Under Water:	APG 24" Blast Cube 44
Peak Pressure	Static Tests:
Impulse	20 mm M97 Projectile:
Energy	HEX-24 Tritonal Torpex
	Foxboro psi 19 12.4 13.0
Underground: Pack Pressure	Catenary psi 46 Duration, microsec 533
	APG 24" Blast Cube 36 24 32
Impulse Energy	
Energy Ov 2552	Heat of:
lame Temperature, OK 2552	Combustion, CBI/Em 419
ctivation Energy, kcal 20.4	
Temp, C 450 to 570 Specific reaction	Gas volume, ee/gm 179
rate, k 1.64 x 10 ⁻⁵	5

Composition: %		Moleculer Weight:	47.6		
Potassium Perchlorat	e 32	Oxygen Balance:			
(17 microns)	\ 1.0	CO. %	-3r -45		
Aluminum, flaked (1		CO %	- 3"		
RDX (through 325 mesh) 16 Asphaltum (through 100 mesh) 4		Density: gm/cc Apparent Pressed at 20,000 psi	9.63		
		Melting Point: °C			
C/h Rotio		Fruezing Point: °C			
Impect Sensitivity, 2 Kg Wt:		Boiling Point: °C			
Bureau of Mines Appara Sample Wt 20 mg	itus, em	Refractive Index, no			
Picatinny Arsenal Appa	rotus, in	_			
Sample Wt, mg		n _B			
		n ₃₀			
Friction Pendulum Test:		Vacuum Stability Test:			
Steel Shoe	Partially detonates	cc/40 Hrs, at			
Fiber Shoe	Unaffected	90°C			
Rifle Bullet Impact Test:	Trials	- 100°C	1.52		
	%	120°C			
Explosions	70	135°C			
Portiols		150°C			
Burned		200 Gram Bomb Sand Test:			
Unaffected		Sand, gm	23.7		
Explosion Temperature:	,c	Sensitivity to Initiation:			
Seconds, 0.1 (no cap us	sed)	Minimum Detonating Charge, gm			
1	***	Mercury Fulminate			
5	545	Lead Azide	0.20		
10		Tetryi	0.25		
15 20		Ballistic Morter, % TNT:			
		Trauzi Test, % TNT:			
75°C International Heat To % Loss in 48 Hrs	est:	Plate Dent Test:			
		Method			
100°C Heat Test:		Condition			
% Loss, 1st 48 Hrs		Confined			
% Loss, 2nd 48 Hrs		Density, gm/cc	-		
Explosion in 100 Hrs		Brisance, % TNT			
Pa 1 141. 4 4		Detonation Rate:			
Flammability Index:		Confinement			
H		- Condition			
Hygrescopicity: %		Charge Diameter, in			
Valetiča.		Density, gm/cc			
Voletility:		Rate, meters/second			

Fragmentation Test:	Shaped Charge Fffectiveness, TNT	= 100:
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones SI	reel Cones
•	Hole Volume	
Density, gm/cc	Hole Depth	
Charge Wt, Ib	, ioia Dapini	
Total No. of Fragments:	Color:	Gray
For TNT		
For Subject HE	Principal Uses: HE filler for	small caliber
3 inch HE, M42A1 Projectile, Lot KC-5:	projectiles	
Density, gm/cc		
Charge Wt, Ib		
Charge VVI, ID		
Total No. of Fragments:	Method of Looding:	Pressed
For TNT]	
For Subject HE		
	Loading Density: gm/cc	1.62
Fregment Velocity: ft/sec	Pressed at 20,000	1.02
At 9 ft	Storage:	
At 25½ ft	30# 05 0.	
Density, gm/cc	Method	Dry
Blast (Relative to TNT):	Hazard Class (Quantity-Distance	(e)
	Compatibility Group	
Air: Peak Pressure	· ·	
Impulse	Exudation	None
Energy		
Litergy	Static Tests:	
Air, Confined:	20 mm T215El Projectile	
Impulse	PA Peak Pressure, ps NFOC 20" Blast Cube	1 77 45
	APG 24" Blast Cube	42
Under Water: Peak Pressure	Static Tests:	
	20 mm M97 Projectile:	
Impulse	HEX-46	THT Tetryl
Energy	Fostoro psi 17.3	2.5 3.5 23 28
Underground:	Duration, microsec 517	560 5 30
Peak Pressure	APG 24" Blast Cube 29	10
Impulse		
Energy	Heat of:	, 3.3.5
Flame lemperature, % 23"2		4119 1735
Activation merg. kent 25.	es Volume, no one	200
lemp. 4,0 to 40		
Specific resction	-·	
rate, k		

Cook-Off Tests:

20 mm T215E1 HEY-48 Loaded Projectiles With Dye-Costed RDX Top-Off

Projectile No.	Cut-Off Temp. C	Cook-Off
1	170	Yes (198)
2	150	No
3	155	Yes (190)
14	150 to 175	No

National Northern Projectile Load:

(c)

MOX-2B (no top-off)	195
MOX-2B (Tetryl top-off)	150
MOX-2B (97/3, RDX/wax top-off)	175
MOX-2 (no top-off)	175

(c)

Fragment Penetration Tests:

			Avg. No. of Penetrations per Round in Zone 550-1300		
Projectile	Filler	Altitude, Feet	0.020"	0.040"	0.051"
T215E1	ਸਾਫ਼ x −48	Ground	352	264	282
	: :	60,000	676	432	388
1282E1	MOX-2B	Ground	634	290	235
		60,000	807	367	250
EX8 Mod 0	MOX-2B	Ground	476	268	224
		60,000	672	264	25 6

The fragment penetration test records numbers of complete penetrations of aluminum panels of various thicknesses at 2.5 feet from the static detonation. The total penetrations recorded on the 24ST-3 aluminum panels occurred with the projectile nose always pointed toward ${\rm C}^{\rm O}$ and the base toward ${\rm 180}^{\rm O}$.

The test data indicate that on the thicker panels, 0.040" and 0.051," the KEX-48 loaded T215E1 projectile produced more comple e fragment penetrations at ground and altitude than MOX-2B loaded T282E1 and EX8 Mod 0 projectiles.

HEX-24; HEX-48

Preparation:

The HEX compositions were prepared by blending the appropriate weight of the dry ingredients in a Patterson-Kelly twin-shell blender for at least 30 minutes.

In alternate procedure for 100 to 200 gram batches used a "Cradle-Roll" mixing device. This device consisted of a half-barrel type container constructed of wood and lined with an electrical conductive material. A plastic roll was allowed to move over the ingredients by remote control action of the container. The roll action prevented caking of the mix but had no adverse effect on the particle size of the ingredients. The period of time required to obtained a uniform and intimate mixture was approximately fifteen minutes.

Origin:

The development of "slow-burning" explosive mixtures which would produce increased blast effects in enclosed or nearly enclosed spaces directed attention to their use for possible military application. In 1950 Picatinny Arsenal developed a high capacity filler for 20mm projectiles consisting of 85/10/5 RDX/aluminum/desensitizer which was more powerful than standard tetryl filler. However, in comparison with MOX type explosives, there was little doubt as to the superior performance of the MOX mixture. HEX (high prergy explosive) mixtures were developed at Picatinny Arsenal in 1953 (Ref a) as superior high big to compositions suitable for use in small caliber projectiles.

- (a) O. E. Sheffield and E. J. Murray, <u>Development of Explosives—Metallized Explosives—High Blast Fillers for Smell Caliber Shell</u>, <u>Picatinny Arsen 1 Memorandum Report No. MR-49</u>, <u>21 December 1953</u>.
- (b) O. E. Sheffield, <u>Properties of MOX-Type Explosive Mixtures</u>, PATR No. 2205, October 1955.
- (c) National Northern Corporation, Letter from Dr. C. M. Saffer, Jr., to Commanding Officer, Picatinny Arsenal, 12 June 195%

³⁵See footnote 1, page 10.

2.4,0.2',1',6'-Hexanitro-oxanilide (EMC)

Composition:	Molecular Weight: $(C_{14}H_6H_2C_{14})$	
c 33.0	Oxygen Balance: CO ₂ % CO %	-53.4 - 9.4
H 1.2 NH NH	Density: gm/cc	
N 21.9 C ₂ N	Melting Point: 'C Decomposes	302
0 43.9	Freezing Point: 'C	
Impact Sensitivity, 2 Kg Wt:	Boiling Point: 'C	
Bureau of Mines Apparatus, cm Sample Wt 20 mg	Refractive Index, no	
Picatinny Arsenal Apparatus, in. 15	n ₂₃	
Sample Wt, mg 12	n ₂₀	
Friction Pendulum Test:	Vacuum Stability Test:	
Steel Shoe Unaffected	cc/40 Hrs, at	
Fiber Shoe Unaffected	90°C	
Riffe Bullet Impact Test: Triais	100°C	0.40
%	120°C	
Explosions	135°C	
Partials	150°C	
Burned	200 Gram Bomb Sand Test:	
Unaffected	Sand, gm	52.1
Explosion Temperature:	Sensitivity to Initiation:	
Seconds, 0.1 (no cop used)	Minimum Detonating Charge, gm	
201	Mercury Fulminate	
5 384	Lead Azide	0.30
10	Tetryl	0.25
15 20	Ballistic Mortar, % TNT:	
	Trauxi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test:	
	Method	
100°C Heet Test:	Condition	
% Loss, 1st 48 Hrs 0.07	Confined	
% Loss, 2nd 48 Hrs 0-05	Density, gm/cc	
Explosion in 100 Hrs None	Brisance, % TNT	
Flemmebility Index:	— Detonation Rate: Confinement	
remmedity index.		
	Condition Charge Diameter, in	
Myerocopicity: % oson and our		
Hygroscopicity: % 25°C, 30% PH 0.1)	Density, gm/cc	

Fragmentation Test:	Shaped Charge Effectiveness, Ti	Shaped Charge Effectiveness, TNT = 100:		
90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Hole Volume Hole Depth	Steel Cones		
Total No. of Fragments: For TNT	Color:	Almost white		
For Subject HE 3 inch HE, M42A* Projectile, Lot KC-5: Density, gm foc Charge Wt, b Total No. of Fragments:	Principal Uses: Igniter pow composition	s		
For TNT For Subject HE		Method of Loading: Pressed and extruded		
Fragment Velocity: ft/sec	Loading Density: gm/cc			
At 9 ft At 25½ ft	Storage:			
Density, gm/cc	Method	Dry		
Blast (Relative to TNT):	Hazard Class (Quantity-Dista	nce) Class 9		
Air: Peak Pressure	Compatibility Group			
Impulse Energy	Exudation	None		
Air, Confined: Impulse				
Under Water: Peak Pressure				
impulse Energy				
Underground: Peak Pressure				
Impulse Energy				

2,4,6,2',4',6'-Hexanitro-oxanilide (HNO)

Solubility in the following substances:

Solvent

<3 gm in 100 cc, at 23° C ~ 5 gm in 100 cc, at 210° C 0.10 gm in 100 cc, at 100° C Ni trobenzene Water Alcohol (Ethyl) Insoluble Acetone Insoluble Benzene Insoluble Butvl acetate Insoluble Carbon tetrachloride Insoluble Dimethylformamide Ether (Ethyl) Very soluble Insoluble Acetic Acid Insoluble Nitric Acid Soluble Crystalline form Long rectangular glistening plates from nitrobenzene

Preparation:

To prepare hexanitro-oxanilide, first prepare tetranitro-oxanilide as described herein under the entry "2,4,2',4'-Tetranitro-oxanilide (TNO)."

A 1.5 liter round bottom flask is equipped with a stirrer of the type which causes a downward swirl. The flask is jacketed for hot and cold water. 187 grams of nitric acid of specific gravity 1.49 (commercial grade) is placed into the flask and 100 grams of sulphuric acid is added to the nitric acid under agitation. The mixed acid is cooled to 10°C. 29.2 grams of tetranitro-oxamilide is slowly added to the mixed acid under rapid agitation maintaining the temperature at 8°-10°C. After the addition of the TNO is completed (approximately 25 minutes) the temperature is raised to 85°C over a period of 2 hours and held at 85°-90°C for one hour. The hexanitro-oxamilide (HNO) "slurry" is filtered on a Fuchrer funnel and purified as explained under "Tetranitro-oxamilide."

Origin:

A. G. Perkin in 1892 obtained hexanitro-oxanilide directly by heating to boiling a solution of tetranitro-oxanilide in a mixture of sulfuric and nitric acids. He also prepared the same compound from oxanilide by the action of a boiling mixture of fuming nitric and sulfuric acids (J Chem Soc $\underline{61}$, 462 (1892)).

- (a) L. Gowen and R. Dwiggens, <u>Case Gun Ignition Studies</u>, NAVORD Report No. 2321, 13 June 1952.
- (b) D. Dubrow and J. Kristal, Substitution of Tetranitro Oxanilide and Hexanitro Oxanilide for Tetranitro Carbazole, PA Pyrotechnic Research Laboratory Report 54-TF1-83, 20 December 1954.
- (c) S. Livingston, Preparation of Tetranitro Carbazole, PA Chemical Research Laboratory Report 136, 330, 11 April 1951.
 - (d) S. Livingston, Development of Improved Ignition Type Powders, PATA No. 2267, July 19 6.

³⁶See footnote 1, page 10.

Composition: CH ₂	Melecular Weight: (Cin H8N8O	296
c 16.8 02n-h n-nc3	Oxygen Brinnes: CO ₂ %	<u> </u>
H 2.7 H ₂ C CH ₂	CO %	-21.6 0.0
N 37.9 02N-N N-NO2	Density: gm/cc Crystal	1.90
0 43.2 CH ₂	Molting Point: *C Capillary a Koffer Micro Bot S	ethod 273
C/H Ratio 0.095	Freezing Feint: *C	
mpact Sanshivity, 2 Kg Wt:	Boiling Point: *C	
Bureau of Mines Apparatus, cm 32 Sample Wt 20 mg	Refrective Index, no	<u> </u>
Picatinny Arsenal Apparatus, in. 9	ng	
Sample Wt, mg 23	n _s	
Friction Pendulum Test:		
Strei Shoe Explodes	Vocuum Stability Test:	
Fiber Shoe Unaffected	90°C	
Rirle Sullet Impact Yest: Trials	100°C	0.37
%	120°C	0.45
Explosions	135°C	••
Pertials	150°C	0.62
Surred	200 Gram Bomb Sand Test:	
Unaffected	Sand, gm	60.4
Explication Temperature: *C	Sensitivity to Initiation:	
Seconds, 0.1 (no cup used) 380	Minimum Detonating Charge,	j m
5 327	Mercury Fulminate	
10 306	Lead Azide	0.30
15	Tetryl	
20	Ballistic Morter, % TNT:	150
75°C International (feat Test:	Trensi Test, % TNT:	145
% Loss in 48 Hrs	Plate Dent Test:	
	Method Condition	
180°C Heat Yest:	Confined	
% Loss, 1st 48 Hrs 0.05 % Loss, 2nd 48 Hrs 0.03	Dencity, gm/cc	
96 Loss, 2nd 48 Hrs 0.03 Explosion in 100 Hrs None	Brisonia 7, 96 TNT	
NOTE TO THE NOTE		
Semmobility Index:	Confinement	
	Conditiun	
Hygrescapicity: %	Charge Diumeter, in.	
30°C, 95% RH (c) 0.00	Density, gm/cc	1.64

beta-HO

leaster Sensitivity Test			Decomposition Equation:	(•)9.7
Condition			Oxygen, atoms/sec	10-5. (
Tetryl, ym			(Z/sec) Heat, kilocaloris/mole	52.7
Wax, in. for 50% Di	rtonation	`	(AH, kcol/mal)	•
Wax, gm			Temperature Ronge, *C	271-314
Density, gm/cc			Phase	Liquid
lest of:			Armer Plate Impact Test:	
Combustion, cal/gm		23¢.`		
Explosion, col/gm	(e)	1356	60 mm Morter Projectile:	
Gas Voiume, cc/g			50% Inert, Velocity, ft/sec	
Formation, cal/gm	(e)	-60.5	Aluminum Fineness	
Fusion, cal/gm				•
			500-lb General Purpose Bombe:	
posific Heat: cal/gm/		stallized (g)		
<u>°c</u>	<u>°с</u>		Plate Thickness, inches	
-75 0.153	85	0.288	1 ,	
0 0.228 25 0.243	90 100	0.290 0.295	1	
50 0.266	125	0.295	1%	
75 0.282	150	0.315	11/2	
· · · · · · · · · · · · · · · · · · ·		-	1%	
Jurning Rate:	•			
cm/sec		·	Bearb Drep Test:	
Thermal Conductivity: cel/sec/cm/°C			17, 2000-th Semi-Armer-Plercing	Bomb vs Concrete
Coefficient of Exponsion			Max Sate Drop, ft	
Linear, %/°C	••		300-16 General Purpose Bomb vi	Concrete:
Volume, %/°C			Height, ft	
	/->		Trials	
Krdnar, Mehe' Scale:	(e)	2.3	Unaffected	
			Low Order .	
roung's Modulus:			High Order	
E', dynas/cm ³				
E, It/inch			Fuco its Gamerat Purpose Sausis vi	Con croto:
Dansity, gm/cc				
			- Height, ft	
Economiative Strangth: I	b/inch*		Trials	
			Unaffected	
Vapor Proceure:			Low Order	
	nm Mercury		High Order	
	•			
			}	

Two men are required to regulate the addition of reagents and control the temperature during the initial stage addition; one men can complete the procedure. A 1-liter 5-necked flask is used, the center neck for an efficient stirrer, one side neck for a thermometer, and the other necks for burrettes and a gas outlet (to water trap). The flask is placed in a pan with steam and cold water inlets, for temperature control.

Five ec of acetic anhydride and 250 cc glacial acetic acid are poured into the flask and the temperature brought to $45 \pm 1^{\circ}$ C, and held there for the duration of the entire reaction. The reagents (a solution of 33.6 gm hexamine in 55 gm of glacial acetic acid, 100 cc of acetic anhydride ard 40 cc of a solution of 42.3/57.7-ammonium nitrate/98% nitric acid) are then added simultaneously, continuously and equivalently over a 25-minute period. The reaction mixture is aged 15 minutes.

The second stage reagents (60 cc of 42.3/57.7, ammonium nitrate/98% nitric acid and 150 cc acetic anhydride) are then added simultaneously, continuously and equivalently over a 25-minute period. The mixture is aged 65 minutes, poured into 1.5 liter of water and simmered on a steam bath for 12 hours. Cool, filter and dry the RDX-BMX precipitate (yield 73% BMX).

The RDK is destroyed, leaving HMX, as follows: 1025 gm of the crude product are placed in a solution of 15 gm sodium tetraborate decahydrate in 5 liters of water, heated to boiling with agitation, and 5 N RacH added at the rate of 3 cc/min. When about 730 cc have been added the pR increases sharply from a little over 6.7 to over 9.7 which corresponds to complete destruction of the WDM. Filter the HMX from the hot mixture; yield 612 gm, mp 279.50-280.50C. Recrystallization from nitromethane yields material selting at 2610-262°C.

Origin:

Was discovered as an impurity (by-product) in the nitration of hexamethylene-tetramine to form REM. It is now samufactured directly by the process described above and has valuable use in explosive systems.

Removal of RDX from H-X-DTX Mixtures and Recovery of a RDX-HMX Mixture (This procedure appears suitable for use with mixtures containing 80% or more HMX):

Procedure:

500 grams of HMT containing 12.25% RDX are placed in a 1500 cc beaker, 500 cc of acetone is added and the slurry is agitated for several minutes at room temperature. Before complete settling, the RDX-MAX-acctone solution is decanted.

To the residual HMX-RDX, another 500 cc of acetone is added. The slurry is heated on the steambath and while holling, agitated for several minutes. The boiling RDX-HMX-acetone solution is decented. The residual HMV is now washed with cold acetone into a funnel. This HMX is now taken up in 95% alcohol, filtered and dried. Yield 353.9 gm or 70.78%.

All the acetume extracts are combined and evaporated to dryness. Yield 137.5 gm or 26.5%.

Yield Balance:

Pure HMX obtained - 353.9 gm	70.78%
Total ROX-HAX mixture recovered -	26.50%
Samples taken during process - 2.4 gm Loss during process	2.24 % 2.48%
Total	100.00%

Various samples were analyzed for RXD content:

ı.	Crude H	OX.	12.25% RDX
2.	After f	irst acetone washing	6.0% RDV
3.	After s	econd acetone washing	2.0% RD(
Ä.	After ti	nird acetone washing	0.0% PTR
		.1	el en one

Proparation of line Particle-size HMX by the Aspirctor Method:

- Dissolve 1100 gm HMX in 4400 cc of dimethyl sulfoxide. Filter the HMX solution.
- Convect a clean aspirator to the water line.
- Convect a clean aspirator to the water line.

 Flace a 55 gallon clean drum under the aspirator.

 Fasten a polyethylene tubing, long enough to reach easily to the bottom of the HMX-dimethyl sulformide container, to the side intake of the aspirator.

 Fasten to the bottom of the aspirator another polyethylene tube long enough to reach to the bottom of the 55 gallon drum.

 Open the water faucet and then place the polyethylene tube in the HMX container.

 Unite milky fine HMX separates out in the drum. Total duration of run is approximately 7 samutam.

- 7 minutes.

 After all the HMX solution is sucked out of the container, the inter is turned off. The material is filtered and water washed.
- 11. If dry HMX is required, the material : n be alcohol and ether washed.

A more efficient method to recover the RDX-HMX mixture:

- 1. Filter the combined hot acetone extracts.
- Pour while agitating the filtered extracts into at least 4 times its volume of water.
 Filter and dry, etc.

beta-HK

Color:

White

Storege:

Mathad

w

Hazard Class (Quant'ty-Distance)

Class 9

Compatibility Group

Group L (dry) Group H (wet)

Emdation

Sone

References: 37

- (:) O. E. Sheffield, E. J. Murray, A. L. Rosen and B. W. Manouse, <u>Properties of HMX</u>, PA Chestial Research Laboratory Report No. 52-TK1-23, 7 April 1952.
 - (b) W. E. Backmann, The Preparation of HMK, OSRD Report No. 1981, 3 November 1943.
- (c) S. Livingston, Characteristics of Explosives HOX and IPEHM, PATR No. 1561, 6 September 1945.
- (d) R. J. Finkelstein and G. Gemow, Theory of the Detonation Process, MAYORD Report No. 90-46, 20 April 1947.
 - (e) O. H. Johnson, HKK as a Military Replosive, MAYORD Report No. 4371, 1 October 1956.
 - (f) Also see the following Picatinny Arsenal Technical Reports on BMX:

1 3 6 7 2 1741 2183 2016 1737 1709 2059

(g) C. Lenchitz, W. Bouch and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

³⁷See footnote 1, page 10.

Composition: %		Melecular Weight:	91
HOCK	49	Oxygen Surener:	
	•	CO ₂ %	-51
THE	29	CO %	-27
Aluminum	55	Density: gm/cc Cast	1.70
•		Malting Puint: °C	
C/H Ratio	· · · · · · · · · · · · · · · · · · ·	Freezing Point: *C	
Impact Fensitivity, 2 Kg Wt: Bureau of Mires Apparatus, cm	••	Selline Velat: 'C	
Sample Wt 20 mg		Remotive linies, no	
Picatinny Arsenal Apparatus, in.	17	ng.	
Sample Wt, mg	25	-	
		n _s	
Friction Pondulum Test:		Vocema Stability Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
Riffe Sullet Impact Test: 10 Triols .	4		
3/16" Steel		120°C	0.37
Explosions 30	50	135°C	
Partials and	**	150°C	
Burned 10		200 Grem Bomb Sand Test:	
Unaffected 0	50	Sand, em	61.3
Explosion Temperature:	°c	Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minircum Detonating Charge, gm	
1		Mircury Fulminate	
5 Flames erraticall	y 370	Lead Azide	0.30
10		Tetryl	****
35		Beflistic Morter, % TNT:	120
20		Treuxi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs		Plote Dent Test:	
70 LOSS IN 40 FIRS		Method	
160°C Keet Test		Condition	
% Loss, 1st 48 Hrs		Confined	
% Loss, 1st 40 Hrs		Density, gm/cc	
Explosion in 100 Hrs		Brisance, % TNT	
		- Derenation Rate:	~ ~~
Flemmebility Index:		Confinement	None
		Condition	Cast
Hygrescopicity: %		Charge Diameter, in.	1.0
		Density, gm/cc	1.90
Yeletility:			/-

Bourtor Sensitivity Test:		Decomposition Equation:	
Condition		Oxygen, atoms/sec	
Tetryl, gm		(Z/səc)	
Wax, in, for 50% Detonation		Heat, kdocolorie/mole (AH, kcs:/mol)	
Wax, gm		Temperature Range, *C	
_		Phose	
Density, gm/cc		Fridae	
Heat of:	4.	Armer Plate Impact Test:	
Combustion, cal/gm	3 687	Anna Part Impart Car.	
Expla;ion, cal/gm	1190	66 mm Morter Projection:	
Gas Volume, cc/gm	680	50% Inert, Velocity, ft/suc	
Formation, cal/gm		Aluminum Fineness	
Fusion, cal/gm			
		500-lb General Purpose Bombs:	
Specific Heat: col/gm/°C 32 ³ to 74 ⁰ C	0.01.5	Plate Thickness, inches	
32 60 74-0	0.245	,	
		<u>j</u> 1	
		134	
		11/2	
<u> </u>		184	
Burning Refe:		7 '*	
cm/scc			
		Somb Drop Test:	
Thornol Conductivity:			
cal/sec/cm/°C		17, 2000-th Semi-Armor-Plotting Bemb vs Conc	refe:
		Max Safe Drop, ft	
Coefficient of Expansion: Linear, %/*C			
Linear, 70; C		500-lb General Purpose Borsh vs Concrete:	
Volume, %/°C		Height, ft	
		Trials	
Herdness, Meh. Seein:		Unaffected	
		Low Order	
Young's Modulus:		High Order	
E', dynes/cm²		riigh Order	
E, lb/inch²		1000-lb General Purputs Bomb vs Cenerate:	
Density, gm/cc		Table is denoted to a poor owner to denote of	
	00/-	Height, ft	
Compressive Strungth: Ib/inch	2260 See below	Trials	
	'∽e neton	Unaffected	
Vapor Prateuro:		Low Order	
°C mm Mercury 2		High Order	
Compressive Strength: lb/inch	*	_	
Average (10 tests)	2360	Ullimate Deformation: %	
High	2530	Average (10 tests) 2.8	81
Low	1910	High 3.4	22

^{*} Test specimen 1/2" x 1/2" cylinder (epproximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwel.

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:				
90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hale Valuine Hole Depth				
Total No. of Fragments: For TNT	Colors	Gray			
For Subject HE 3 inch HE, :442A1 Projectile, Let KC-S: Density, gm/cc Charge Wt, Ib	Principal Uses: HE projectile and bom	b filler			
Total Mo. of Fragments: For TNT For Subject HE	Method of Looding:	Cast			
Fragment Velocity: ft/sec	Leading Density: gm/cc	1.90			
At 9 ft At 251/4 ft	Storage:				
Density, gm/cc	Method	Lary			
Black (Relative to THT):	Hazard Class (Quantity-Distance)	Class 9			
Air: Pok Pressure Impulse Energy	Compatibility Group Exudation	Group I			
Air, Conflood: Impulse	Work to Produce Run west ft-1b/inch Average (15 tests) 2. High 3. Low 2.	77 39			
Peak Pressure Impulse Energy	Efflux Viscosit; Saybolt Seconds:	24.8			
Underground: Peak Pressure Impulse Energy	·				
च्च च ा प्र 7	*Test specimen 1/2" x 1/2" cylinder mately 3 gm) pressed at 3 tons (6,0 total load or 30,000 psi with a 2 time of dwell.	2000 1ь)			

Modulus of Elasticity: *

		lb/inch ²
Average	-	89,200
High	;	97,400
Low	;	76,300

* Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Setback Sensitivity Test:

Critical Pressure	119,000 psi *
Density, gm/cc	1.92

* Pressure below which no initiation is obtained and above which an increasing percentage of initiations can be expected as the setback pressure increases.

Preparation:

Procedure similar to that used for Torpex.

References: 38

- (a) 1st Indorsement from Chief, Explosives Development Section, to Chief, Explosives Research Section, Picatinny Arsenal, dated 12 May 1953. Subject: "Properties of Octols and HTA-3."
- (b) R. Brown and R. Velicky, Heat Capacity of HTM-3, Picatinny Arsenal General Laboratory Report No. 58-H1-509, 5 May 1958.

³⁸See footnote 1, page 10.

Lead Azide

Composition:	AA-Barrier Mark Aa			
%	Melecular Weight: (PbN ₆) 291			
n 28.8	Ch; yen Belence: Ch; % -5.5 Ct' % -5.5			
Pb 71.2	Density: gm/cc Crystel 4.80 Dextripated 4.38			
	Melting Nint: *C Decomposes			
C/H Ratio	Freezing Point: "C			
Bureau of Mines Apparatus, cm 10 Dextrinated	Bailing Paint: *C			
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 5 Sample Wt, mg 30 28	Refractive lades. no			
Friction Pendulus: Test:	Vecum Stability Test: Dextrinated			
Steel Shoe Explodes	cc/40 Hrs, at			
Fiber Shoe Explodes	90°C			
Rifle Bullet Impact Teet: Trials	- 100°C 1.0			
%	120°C 0.07			
Explosions	153°C			
Partiols Burry.d				
U:infiected	200 Grum Bomb Send Test:			
V. W. C.	Black powder fuse 19.			
Explosion Temperature: 'C	Scasitivity to Initiation:			
Seconds, 0.1 (no cap used) 390	Minimum Detonating Charge, gm			
1 356 5 Explores 340	Mercury Fulminate Lead Azide			
10 335	Tetryl			
15 335				
20 335	Bellistic Morter, % TNT:			
75°C International Heat Test:	Trouxi Test, % TNT: (a) 39			
% Loss in 48 H-s	Plate Dent Test:			
100°C Heet Test:	Condition			
% Loss, 1st 48 Hrs 0.34	Confined			
% Loss, 2nd 48 Hrs 0.05	Density, gm/cc			
Explosion in 100 Hrs None	Brisance, % TNT			
Flommshilty Index:	Detenution Rate: Pure Lead Azide Confinement			
Mygrescepicity: % Dextrinated Not Dextrinated 0.8 0.03	Condition Pressed Charge Diameter, in.			
Veletility:	Density, gm/cc 2.0 3.0 4.0 Rate, meters/second 4070 4630 5180			

Lead Azide

Fragmentation Test:	Shaped Charge Effectiveness	Shaped Charge Effectiveness. TNT = 100:		
90 mm HE, AZTI Projectile, Let WC-91:	Glass Cone	uties Cones		
Density, gm/cc	Hole Volume			
Charge Wt, Ib	Hole Depth			
Total No. of Fragments:	Colors	White-buff		
For TNT	1150	WILL CO-DUIT		
For Subject HE	Data de al Herre			
3 inch itE, M42A1 Projectile, Let KC-5:	and comme	es, priming composition proise blasting caps		
Density, gm/cc				
Charge Wt, Ib				
Total No. of Fragments:	Mathad of Lookson			
For TNT	Method of Looding:	Pressed		
For Subject HE				
	Leading Density: gm/cc	psi x 10 ³		
Fragment Velocity: ft/sec	3 5 10	. 15		
At 9 ft	2.62 2.71 2.96	3.07		
At 251/4 ft	Sir yes			
Density, gm/cc	1			
	Method	Wet		
Stact (Relative to TNT):	Hazard Class (Quantity-D	istonce) Class 9		
Air:	Compatibility Group	Group M (wet		
Peak Pressure	1			
mpulse	Exudation	None		
Energy				
				
Air, Confined:	Compatibility with Met	als:		
Impulse	Dry lead azide does	not react with or cor-		
	rode steel, iron, nick	el, aluminum, lead,		
Under Water:	zinc, copper, tin or c			
Peak Pressure	affect coatings of aci	d-proof tlack paint, hellac. Lead azide in		
Impulsa	the presence of moistu	re corroles zinc and		
Energy		r, it forms the extreme		
Undergreend:	Specific Heat: cal/gm/	°c		
Pack Pressure	°C			
Impulse	-50	0.110		
Energy	Ô	0.110		
Heat of:	25	0.110		
Combustion, cal/gm 630	50	0.110		
Explosion, cal/gm 367	Thermal Conductivity:			
Gas Volume, cc/gm 308				
Formation, cal/gm -346	cal/sec/cm/°C (Pure) 1.55 x 10 ⁻⁴		

Load Azide

Compatibility with Natale:

Dry: Steel, iron, nickel, aluminum, lead, zinc, copper, tin, stainless steel, brass and bronze were unaffected by six years' contact with dry lead aside at ambient temperature and 50°C. Momel, chrome-mickel and Incomel were unaffected under the same conditions in two and one-balf years.

Net: Copper and sine are rapidly attacked by moist lead szide, while aluminum is not attacked in 24 hours. Homel, chrome-nickel and Incomel are not attacked by lead szide (25 moisture) after 29 months' exposure at ambient temperature and 50°C, and J-1 magnesium-sluminum alloy is very slightly corroded.

Sample Tested	Leed Azide	P	Azide lus Water	Lead A	8	plus 20% Ethyl Alco- hol (95%)
Friction Pendulum Te	et:					
(All IA destrinated)						
Shoe	Piber	Fiber	Steel	Filber	Steel	Fiber
Ho. of Trials Explosions Gracklings Unaffected	1 0	10 0 10	12 0 2 10	10 0 0 10	1 5 1	1 1 0 0
Jupect Sensitivity,	2 Kg kt:					
(All IA dextrinated)						
PA Apparatus, inc	hes 4	9)		9	4
Activation Energy: (c)					
Koel/mole Induction Period,	seconds	23.74 0.5-10				
Initiating Efficient	v, Grams Requ	ired to Gi	ve Comple	te Initia	tions of:	
		Dextrinat	ed Azioe	(gm)		
TMT Tetryl ROX PMTM			0.25 0.10 0.05 0.02			
Bensitivity to Stati	c Discharge,	Joules (Po	re Lead A	zide) (b)		0.0070

Leed Azide

Compatibility of Dextrinated Lead Azide with Black Powder: 100°C Vacuum Stability Test, cc/40 hr:

Sample Wt (gra)	Material	cc
1.0	Lead Azide	0.50
1.0	Black Powder	0.38
2.0	50/50.lend Azide/Black Powder	1.26

Solubility of Pure Lead Azide; gm/100 gm of Water:

<u>ос</u>	£
20	0.05

Preparation of Load Azide (Dextrinated): (du Pont procedure)

2 Ha - N = N = N +
$$70 (100_3)_2 \rightarrow Pb(N_3)_2 + 2 NaNO_3$$

Lead nitrate solution: This is prepared by dissolving 164 lbs lead nitrate and 8.25 lb. dextrine in deionized water, the solution allowed to settle, and sodium hydroxide added to bring the solution to a pH of 5.4. The final concentration of the solution is then adjusted to 7.4% lead nitrate, 0.375% dextrine by addition of deionized water.

The lead axios is precipitated at a solution temperature of 160°F, using 60 parts lead nitrate and 50 parts sodium exide solution. The latter is added to the former in 23 minutes, under agitation (no baffles are used in the precipitation vessel), the mixture cooled to room temperaturs in 12 minutes, and allowed to settle 10 minutes. The mather liquor is decented and the remaining slurry washed before packing.

Origin:

First prepared in 1891 by T. Curtius (Ber 24, 3345-6) by adding lead acetate to a solution of sodium or ammonium azide. F. Hyronisus (French Patent 364,792) should be credited with the first attempt in 1907 to use lead azide with some success in the emplosive industry. Its commercial manufacture started in Burye before World War II and in the United States since 1931 as military or commercial grade "dextrinated" lead azide.

Destruction by Chemical Decomposition:

Lead axide can be decomposed by

- (1) mixing with at least five times its weight of a 10% solution of sodium hydroxide and allowing the mixture to stand for 16 hours. Decant the supermatant solution of sodium azide and drain into the soil.
- (2) dissolving in a 10% solution of ammonium accrete and adding a 10% solution of sodium or potassium bichromate until no more lead chromate is precipitated.
- (3) wetting with 500 times its weight of water, slowly adding 12 times its weight of 25% sodium mitrite, stirring, and then adding 14 times its weight of 36% nitric or glacial acetic acid. A red color produced by the addition of ferric chloride solution indicates Lead Azide is still present.

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Lead Azide

(4) dissolving in 50 times its weight of 15% ceric ammonium nitrate. The azide is decomposed with the evolution of nitrogen.

References: 39

- (a) Ph. Haoum, Z ges Schiess Sprengstoffe, 181, 229, 267 (27 June 1932).
- (b) F. W. Brown, D. H. Kuzler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Burcau of Mines, RI 3852, 1946.
- (c) C. Lenchitz, Ice Calorimeter Determination of Enthalry and Specific Heat of Eleven Organometallic Compounds, PATR 2224, November 1955.
 - (d) Also see the following Picatinuy Assemal Technical Reports on Lead Azide:

<u>o</u>	1	2	3	4	2	<u>6</u>	I	<u>8</u>	2
550 580 600 760 1450	561 861 1451 1651	832 852 882 932 1132 1152 1352 1372	393 1393 1493 2093 2133	2164 2164 2164 234	255 525 1 3 25 1485	326 856 866 1316 1486 1556	567 637 657 707 1737 2227	628 708 748 788 836 1388 1528 1638 2198	609 719 749 769 849 999 2179

³⁹See footnote 1, page 10.

Composition:	Melacular Weight: (PbC6H2N2O6) 405
C 17.8 H 0.5 N 6.9	Oxygen Belence: CO ₂ % -32 CO % - 8
0 23.7 Pb 51.1	Density: gm/cc Crystal 3.2
<u>\</u>	Melting Point: 'C
C/H Ratio 0.549	Freezing Point: *C
Burgou of Mines Apparatus, cm 1 kg at 30	Boiling Point: 'C
Bureau of Mines Apparatus, cm 1 kg wt 30 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 20	Refractive Index, no
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vecuum Stebility Test: cc/40 Hrs, at 90°C 100°C
Rifle Bullet Impact Test: Trials 96 Explosions Partials	120°C (73 minutes) Explodes 135°C 150°C
Burned Unoffected	200 Grem Bemb Send Test: Sand am Black powder fuse 20
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Explodes 265 10 15	Sassitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
20	Bellistic Morter, % TNT:
	Trouzi Test, % TNT:
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Alerino
100°C Heart Test:	Condition Confined
% Loss, 1st 48 Hrs 0.20	Density, grr/cc
% Loss, 2nd 48 Hrs 3.02 Explosion in 100 Hrs None	Brisance, % TNT
Flammability Index:	Detenation Rate: Confinement
Hygrescapicity: % 30°C, 90% RH 0.73	Condition Charge Diameter, in.
Volatility:	Density, gm/cc Rate, meters/second

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Lead 2,4-Dinitroresorcinate (LDNR)

r yellow detonators Pressed Wet Class 9
Pressed Wet Class 9
Pressed Wet Class 9
Wet Class 9
Class 9
Class 9
Class 9
•
None
LDNR does not
270
·

Preparation:

To a solution of 5 grams of purified dinitroresorcin and 2.65 grams of anhydrous sodium to in 500 ec of boiling water is added slowly a solution of 10 grams of lead nitrate assolved in 60 ec of boiling water. The reaction mixture is constantly stirred during the addition of the lead salt and for about an hour afterward while the solution is allowed to cook to room temperature. The precipitate is filtered and washed thoroughly first with water and then with alcohol as either. It is dried in a steam oven.

Origin:

2,4-dinitroresorein was described in the 1881 edition of Beilstein (Beil VII, 885). The same conjound was described in more detail by Weselsky, Benedikt and Ribl in 1882 (M II, 323). The land salt of 2,4-dinitroresoreinol appears to have been prepared between World War I and World War II by treating resoreinol with nitrous acid and oxidizing the resulting dinitrosoresoreinol to dinitroresoreinol. Lead nitrate solution was then added to a solution of the 2,4-dinitroresoreinol to which sodium carbonate had been added to form the soluble sodium salt (J. D. Fopper, PATR No. 480, March 1954). The LYBR exists in two forms differing in physical characteristics but possessing similar explosive properties. These forms are red and orange in color (K. S. Warren, PATR 1448, September 1944).

sfer 40

(a) See the following Picatinny Arsenal Technical Reports on Lead 2,4-Dinitroresorcinate:

<u>o</u>	3	<u>4</u>	<u>8</u>	2
480 580	453	1004	1328 1448	859 1079

⁴⁰See footnote 1, page 10.

Lead 4,6-Dinitroresorcinol Basic (LDNR Basic)

Composition:	Meloculer Weight: (Pb2C6H4N2O8) 646
% 0-P5-OH C 11.2 H 0.6 N 4.3 02N	Oxygen Science: -20 CO₂ % -5
0 19.8 Pb 64.1	Density: gm/cc
NO ²	Melting Point: °C 213
C/H Ratio 0.177	Freezing Point: *C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 1 kg vt 60	Bailing Point: *C
Sample Wt 20 mg Picaninny Arsenal Apparatus, in. Sample Wt, mg 20	Refrective Index, no. no. no.
Friction Pondulum Test: Steel Shoe Fiber Shoe	Vector Stability Test: cc/40 Hrs, at 90°C
Riffe Bullet Impact Test: Trials ### Explosions Partials	100°C 120°C 135°C 150°C
Burned Unaffected	200 Green Bomb Sond Test: SMGsP Bowder fuse 15
Explosion Temperature: *C Seconds, 0.1 (no cop used) 1 5 Explodes 295 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl Belliatic Morter, % 'ENT:
	Trouzi Test, % TNT:
75°C Internetional Heat Test: % Loss in 48 Hrs	Plate Dent Test: Methori
100°C Heat Test:	Condition Confined
% Loss, 1st 48 Hrs 0.4 % Loss, 2nd 48 Hrs 0.0	Density, gm/cc
Explosion in 100 Hrs None	Brisance, % TNT
Flommability Index:	Detenation Rate: Confinement
Hygrescepicity: %	Condition Charge Diameter, in
Voletility:	Density, gm/cc Rate, meters/sucond

Lead 4,6-Dinitrorenorcinol Basic (LDNR Basic)

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regressiation Test:	Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile, Let WC-91:	Glass Cones Steel Cones
Density, gm/cc	Hole Volume
Charge Wt, Ib	Hole Depth
Total No. of Fragments:	Color: Red or yellow
For TNT	
For Subject HE	Principal Uses: Electric detonators
3 inch HE, M42A1 Projectile, Let KC-5:	
Density, gm/cc	
Charge Wt, Ib	
Total No. of Fragments:	Method of Looding: Pressed
For TNT	Treaser.
For Subject HE	
	Leading Dentity: gm/cc
regment Velocity: ft/sec	
At 9 ft	
At 251/4 ft	Storege:
Density, gm/cc	Method Wet
	THE
last (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9
Airs	Compatibility Group
Peak Pressure	
Impulse	Exudation Kone
Energy	
<u> </u>	Tuthtaking Detterance O.b. on 1700 Dank
Air, Confined:	Initiating Efficiency: 0.4 gm LDNR Basic does not initiate tetryl pressed at 3000
Impulse	pai.
Under Water:	
Peak Pressure	
Impulse	
Energy	
Underground:	
Peak Pressure	1
Impulse	
Energy	
	į
	I

AMCP 706-177

Lead 4,6-Dinitroresorcinol Basic (LDNR Basic)

Preparation:

- (a) One hundred grams of pure resorcin is fused in a porcelain casserole and immediately poured on a glass plate. After cooling, the cake is ground in a mortar to pass a U. S. Standard No. 6 mesh screen. Four hundred grams of 98 percent nitric acid in a one pint capacity Dewar jar is stirred mechanically while carbon dioxide snow is added in small pieces. When the temperature falls to -20°C, 40 grams of the granulated resorcin is added in small quantities. Simultaneous addition of solid carbon dioxide as required prevents a rise of temperature of more than 5 degrees throughout the entire experiment. Five minutes after the last portion of resorcin is introduced, the mixture is further cooled to minus 50°C, and finally drowned with vigorous stirring in five times its volume of cracked ice, in water. This mixture is allowed to stand for one hour and the product then filtered, washed, and partially dried, weight \$3.6 grams. The crude \$4.6-DRR is purified by first dissolving the product in an aqueous 5 percent sodium hydroxide solution (17.4 grams of sodium hydroxide in 3%0 cc of water). The resulting solution is then neutralized by gradually adding it to a boiling solution of 21.4 grams of 96 percent sulphuric acid in 150 cc of water. The resulting precipitate of \$4.6-DRR is filtered hot on a suction filter and air-dried. Yield, 27.5 grams (37.8 percent of the theoretical).
- (b) Five hundredths (0.05) mole (18.96 grams) of lead acetate is dissolved in 67 cc of warm water, into which is gradually stirred 0.10 mole (4.0 grams) of sodium hydroxide dissolved in 67 cc of water. Stirring is continued for five minutes. After settling, the white lead hydroxide is washed by decentation three times with 100 cc portions of distilled water, and used immediately for the next operation.
- (c) A 0.0278 mole (5.56 grams) quantity of the 4,6-IMR prepared under (a) above, is dispersed in 270 cc of water by vigorously beating with a motor stirrer. After heating this dispersion to 90°C, the 0.05 mole of lead hydroxide prepared above in slurry form is introduced in small portions. Agitation is continued for three hours at 90°C. The basic lead 4,6-IMR is washed duce by decantation, and again on the filter with alcohol. After drying overnight in a desiccator charged with calcium chloride, the product weighs 15.6 grams.

Origin:

Both the 2,4- and 4,6-dinitroresorcin were described in some detail by Weselsky, Benedikt and Hübl in 1882 (M II, 323). Typke prepared the 4,6-dinitroresorcin in 1883 by hydrolyzing the nitration product of resorcin discetate (Ber 16, 551). A sore direct and economical method of preparation suitable for production scale manufacture was developed during World War II by the British (Ministry of Supply Pouch Item W-154-21s, "Manufacture of 4,6-Dinitroresorcin and Lead 4,6-Dinitroresorcinate"). This procedure consisted of preparing 4,6-dinitroresorcinol by direct nitration of granulated resorcin and allowing the product in slurry to react with an excess of lead hydroxide at 90°C. This basic salt can be prepared in two forms: (1) a micro-crystalline, yellow, low-density form and (2) a denser, brick-red form. Both products have the same chemical composition and the same sensitivity to impact (PATE 1448, September 1944).

Lead Styphnate

Composition:	Molecular Weight: (PbC6H3N3O9) 468	
C 15.4 H 0.6 N 9.0	Oxygen Belance: CO ₂ % -19 CO % 2	
0 30.8 Pb 44.2	Density: gm/cc Crystal 3.02	
NO ₂	Molting Point: °C Explodes 260-310	
C/H Ratio 0.320 - 2	Freezing Point: *C	
Impact Sociality, 2 Kg We: Bureau of Mines Apparatus, cm	Boiling Point: °C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3; (8 oz wt) Sample Wt, mg	Refrective Index, no. no. no. no.	
Friction Pendulum Test:	Vacuum Stability Tert:	_
Steel Shoe Detonates Fiber Shoe Detonates	cc/40 Hrs, at 90°C	
	100°C 0.4	
Riffie Bullet Impact Test: Triols	120°C 0.3	
% Explosions	135°C	
Partials	150°C	
Burned	200 Grem Bemb Sand Test:	
Unaffected	Sond om 24 Black powder fuse 11.1	
Explanion Temperature: 'C		
Explosion Temperature: 'C Seconds, 0.1 (no cap used)	Sensitivity to Initiation: Minimum Detonating Charge, gm	
1	Mercury Fulminate Trace#	
5 Explodes 282	Lead Azide Trace	
10 276	* <. Of gm, alternative	
15 272		
2C 267	Ballietic Morter, % TNT:	
TRIC International Mana Tout.	Treuxi Test, % TNT: (a) 40	
75°C International Heat Tent: % Loss in 48 Hrs	Plate Dent Test: Method	
100°C Heat Test:	Condition	
% Loss, 1st 48 Hrs 0.38	Confined	
% Loss, 2nd 48 Hrs 0.73	Density, gm/cs	
Explosion in 100 Hrs None	Brisance, % TNT	
Flommability Index:	Detenction Rate: Confinement	
Hygruscapicity: % 25°C, 100% RH 0.05 30°C, 90% RH 0.02	Condition Charge Diumeter	
Volutility:	Density, gm/cc 2.9	
	Rate, meters/second 5200	

Lead Styphnate

Fregmentation Test:	Sheped Charge Effectiveness, TNT :=	1 00 :
90 mm HE, M71 Projectile, Let WC-91:	Glass Cones Steel	Cones
Density, gm/cc	Hole Volume	
Charge Wt, Ib	Hole Depth	
Total No. of Fragments:	Color: Orange-reddish b	rown
For TNT		
For Subject HE	Principal Uses: Igniting charge,	and ingrediert
3 inch HE, M42A1 Projectile, Let KC-5:	of priming compo	
Density, gm/cc	1 }	
Charge Wt, Ib		
Total No. of Fragments:	Mished of Loading:	Pressed
For TNT	1	
For Subject HE	Leeding Density: grn/cc	
Frequent Velocity: ft/sec	and the same of th	
At 9 ft At 251/2 ft	Storege:	
Density, gm/cc	Method	Wet
Signt (Relative to TNT):	Hazard Class (Quantity-Distance)	Class 9
Air:	Compatibility Group	Group M (wet)
Peak Pressure		
Impulse	Exudation	None
Energy		
Air, Confined:	Activation Energy:	
Impulse	kcal/mol	75 ·3 9
Under Water:	Induction Period, sec	0.5-10
Pook Pressure	2	(c)
Impulsy	Specific Heat: cal/cm/°C	(6)
Energy	<u>°c</u>	
Underground:	-50	0.141 0.158
Peak Pressure	0 25	0.164
Impulse	50	9.167
Energy		
Hest of:		
Combustion, cal/gm 1251 Explosion, cal/gm 457		
Ges Volume, cc/gm 368 Formation, cal/gm -92		
Formation, cal/gm -92		

STATE OF THE PROPERTY OF THE PARTY OF THE PA

Preparation:

Dissolve 14.4 gm lead nitrate and 1 cc of 36% acetic axid in 320 cc distilled water. Dissolve 4 gm 2,4,6-trinitroresorcinol and 1.73 gm sodium componate in 80 cc distilled water. Add the 1.ed acetate solution to the trinitroresorcinol solution, under agitation, keeping the temperature at 70°-75°C and continue stirring for 3 hours at this temperature. Cool to 20°C in 5 hours. Evaporate the solution to 1/3 its volume, cool, filter and wash the product well with water (to neutrality).

Sensitivity to Static Discharge, joules: (b)	0.0009
Loss in Weight at 105°C: \$	
3 hours 6 hours 9 hours	0.02 0.23 0.23
Effect of Storage for 2 Months at 30°C, on:	
Explosion Temperature Test Value Sand Test Value	Nil Nil

Sensitivity to Initiation Solubility, gm/100 gm (\$) in:

Glycol Diacetate

°c ½

20-25 0.1

Origin:

First described in 1914 by von Hurtz and found to be a relatively poor initiator by Wallbaum in comparison to other primary explosives. (Z ges Schiess Sprengstoffw 34, 126, 161, 197 (1939)). Moisak showed that lead styphnate could be used as an insulating (cover) material for lead azide providing protection from mechanical and chemical influences and, at the same time, increasing the detonating ability of the total charge (Transactions of Butlerov Inst Chem Tech Kasen (Russia) 2, 81-5 (1935).

Lead Styphnate

Destruction by Chemical Decomposition:

Lead styphnate is decomposed by dissolving it in at least 40 times its weight of 20% socium hydroxide or 100 times its weight of 20% ammonium acetate and adding a solution of sodium dichromate, equal to half the weight of styphnate and 10 parts of water.

References: 41

- (a) Suport AC-9,56/Org Ex 74.
- (b) F. W. Brown, D. H. Kurler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.
- (c) C. Lenchitz, Ice Calorimeter Determination of Enthalpy and Specific Heat of Eleven.
 Organometallic Compounds, PATR No. 2224, November 1955.
 - (d) Also see the following Picatinny Arsenal Technical Reports on Lead Styphnate:

<u>o</u> .	<u>1</u>	2	<u>3</u>	<u> 4</u>	<u>6</u>	I	<u>8</u>	2
1450 2220	11	1352 2032	453 20 93	2164	1316	407 1737 2077	318	2179

⁴¹See footnote 1, page 10,

Mannitol Hamanitrate (Nitromannite)

Composition: CH2ONO2	Molecular Weight (C6H8N6O18) 452
O_NOCH	Oxygen Belance:
O MOGR	CO ₃ % 7.1 CO % 28 3
NOONO .	Density: gm/cc 1.73
ж 18.6 номо ₂	Melhing Paint: °C 112-113
0 63.8 CH ₂ ONO ₂	
C/H Ratio 0.133	Freezing Point: *C
Impect Sonsitivity, 2 Kg Wr: Bureou of Mines Apparatus, cm 11	Builing Point: °C Decomposes 150
Sample 1/1 20 mg	Refrective Index, no.
Picotinny Arsenot Apparatus, in. 4 Somole Wt. mc 31	n 💂
Sample Wt; mg	n _{so}
Friction Pendulum Tost:	Vecuum Stebility Test:
Steel Shoe Detonates	cc/40 Hrs, at
Fiber Shos Unaffected	90°C
Riffe Bullet Impact Test: Tricls	100°C
%	120°C
Explosions	135°C
Partials	130°C
Burned	200 Gram Famb Sand Test:
Unoffected	Sand, ;m 68.5
Explacion Temperature: "C	Sansitivity to Initiation:
Seconds, 0.1 (no cop used) 160-170 (a)	Minimum Detanating Charge, gm
1 232 (b) 5 175 (c)	Mercury Fulminate
5 175 (c)	Lead Azide 0.06
15	Tetryl
20	Ballistic Morter, % THT:
	Trous Test, % TNT: (c) 172
75°C International Heat Test: % Loss in 48 Hrs 0-4	Plate Deat Test: Method
10010 Mark Tank	Condition
100 °C Heat Test: % Loss, 1st 48 Hrs	Confined
% Loss, 2nd 48 Hrs	Density, gm/cc
Explosion in 100 Hrs (Frothed) 48 hours	Brisance, % TNT
Explosion in too instance to hours	— Detenation Rate: (d)
Flammab#Ay Index:	Confinement Yes
	Condition Pressed
	Ct Di
Hygrescopicity: % 30°C, 99% III 0.3.7	Charge Diameter, in. 0-5
Mygreccepicity: % 30°C, 90% RH 0.1.7 Volctility:	Density, gm/cc 1.73 Rate_meters/second 8250

Mannitol Hexanitrate (Nitromannite)

Fragmentation Test:	Shapird Charge Effectiveness, TNT = 100:	,
90 mm HE, M71 Projectile, Let WC-91:	Flass Cones Steel Cones	•
Density, gm/cc	Hole Volume	
Charge Wt, Ib	Hole Depth	
Total No. of Fragments:		
For TNT	Color:	
For Subject HE		· .
	Principal Uses: Secondary charge in det	onators
3 inch HS, M42A1 Projectile, Let KC-5:	(ref i), and in blasting caps des be initiated by a fuse (ref j)	igned t
Density, gm/cc	, , , , , , , , , , , , , , , , , , , ,	
Charge Wt, Ib		•
Total No. of Freyments:	Method of Leading: Pres	
For TNT	Method of Leeding: Pres	sed
For Subject HE		
	Leeding Density: gm/cc	. *
regment Velocity: ft/sec		
At 9 ft At 25½ ft	*a	
	Sterege:	
Density, gm/cc	Method Dry	
lest (Relative to TNT):	Hozard Class (Quantity-Distance) Class	9
Airz	Compatibility Group	
Peak Pressure	Containomy Group	
Impulse	Exudation None	
Energy	none	
Creatgy		
Air, Confined:	65.5°(Kl Test:	
Impulse	Minutes 6	
10-A M	Manages 0	
Under Weter: Peak Pressure	Heat of: (e, f, g)	
Impulse	Combustion, cal/gm 1515 1525	-
Energy	Explosio, cal/gm 1390 1454 1468	1520 66
Underground:	1, 5 55 5	,
Peak Pressure	·	
Impulse		
Energy		
	.]	

Mannitol Hexanitrate (Nitromannite)

Solubility:

- a. Insoluble in water.
- b. Slightly soluble in cold alcohol (2.9 gm at 13°C).
- c. Slightly soluble in ether (4 gm at 9°C).
- d. Very soluble in hot alcohol.

Preparation: (Laboratory Method) (k)

- Cool to below 0°C, 50 gm of 98%-100% nitric acid placed in a 300 milliliter Erlenmeyer Pyrex flask provided with a thermometer and immersed in an ice-salt mixture.
- b. Introduce in small portions, 10 gm of d-mannitol, while swirling the clask to break up any lumps of mannite which might form. Keep the temperature below 0°C.
- c. After solution is complete, add 100 gm of concentrated sulfuric acid from a dropping funnel, swirling the flask in an ice-salt mixture to keep the temperature below 0°C.
- d. Filter the resulting porridge-like slurry through a filter paper previously hardened by treatment with mixed acid.
- e. Rinse the precipitate directly on the filter with water followed by dilute aqueous sodium carbonate and finally with water. (The resulting crude mannitol hexanitrate gives 15.2% H as altermined by the nitrometer.)
- Dissolve the crude mannitol hexanitrate in boiling alcohol and filter through a waterheated funnel.
- Bring the filtrate to boiling and gradually add hot water until the appearance of the first turbidity.
- h. Cool in an ice-salt bath, separate and dry the crystals. (Yield should be about 23 gm of material, melting at 1120-1130C and having 18.58% N, the nitrogen being determined by the nitrometer. Theoretical yield would be 24.8 gm.)

Mannitol hexanitrate was discovered in 1847 by Ascanio Sobrero who recommended it as a substitute for mercury fulminate in percussion caps (Comp rend. 1847, 121). It is the hexanitric ester of d-ramnitol which is widely distributed in nature, particularly in the plant Frankous ornus. N. Sokoloff, a Russian chemist, investigated the explosive properties of his and recommended in 1878 a method of preparation. Mannitol hexanitrate was thoroughly studied by Merthelot, Sarran and Vicille. Example, Menard, Strecker, Tichanowich (Ph. Naoum, Nitroglycerin and Nitroglycerin Emplosives, Baltimore, 1928, pp. 156, 247-250), and particularly by J. H. Wigner (Ber 36, 796 (1903)). More recent data have been reviewed by Guastalla and Racciu ("Modern Emplosives," Industria Chimica 8, 1093-1102 (1933)).

References:42

(a) G. C. Hale, Abstract of Available Information on the Preparation and Explosive Properties of Hexanitromannite, PA Special Report No. 238, 30 July 1925.

⁴²See footnote 1, page 1C.

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Mannitol Hexanitrate (Nitromannite)

- (b) C. A. Taylor and W. H. Rinkenbach, "Sensitiveness of Detoneting Compounds to Frictional Impact, and Heat," J. Frank Inst 204, 369-76 (1927).
 - (c) Ph. Haoum, Z ges Schiess Sprengstoffw (Munich), pp. 181, 229, 267 (27 June 1932).
 - (d) H. Kast, Z angew Chem, 36, 74 (1923).
 - (e) A. Schmidt, Z ges Schiess Sprengstoffw 29, 262, (1934).

 Isodolt and Börnstein, E III, p. 2914.
- (?) A. Marshall, Explosives, Their Manufacture, Properties, Tests, and History, Vol III, London (1932) p. 39. Ph. Macum, Mitroglycerin and Mitroglycerin Explosives, Baltimore, (1926), pp. 156, 247-250.
- (g) A. Schmidt, Z ges Schiess Sprengstoffw 29, 262 (1934) G. Fleury, L. Brissend and P. Ihoste, "Structure and Stability of Mitric Esters," Comp rend 224, 1016-18 (1947). W. R. Tomlinson, Jr., Fundamental Properties of High Explosives. Thermodynamic Relations for Use in the Estimation of Explosive Properties, PATR No. 1651, 22 April 1947.
 - (h) Sarran and Vielle, Mem poudr 2, 161 (1884-1889).
 - (i) L. von Hurtz, U. S. Patent 1,878,652 (20 September 1932).
 - (j) L. A. Burrows, U. S. Patent 2,427,899 (23 September 1947).
- (k) B. T. Fedoroff, Bandbook of Explosive and Related Items, Picatinny Arsensl (unpublished).
- (i) O. E. Sheffield, Literature Survey on Munnitol Hexanitrate, PA Chemical Research Laboratory Report No. 52-TMI-16, 23 January 1952.
 - (m) Also see the following Picatinny Arsenal Technical Reports on Manmitol Hemanitrate:

2 ½ 2 6 1352 24 85 6

Mercury Fulminate

Composition:	Addanda Malaha (n.a.n.a.)
%	Molecular Weight: (HgC ₂ N ₂ O ₂) 285
$c = 8.4 \qquad o-n-c$	Oxygen Belence:
	CO ₂ % -17 .5.5
	Density: gm/cc Crystal 4.43
0 11.2 0 -N - C	AA-Di Di A
Hg 70.6 C/H Ratio	
	Freezing Point: *C
Impact Sensitivity, 2 Kg Wt: Bureou of Mines Apparatus, cm 5; (1 kg Vt) 35	Bolfag Point: *C
Sample Wt 20 mg	Refrective Index, no
Picatinny Arsenal Apparatus, in. 2; (1 1b wt) 4 Sample Wt, rng 30	I _D
55	n <u>e</u>
Friction Fendulum Test:	
Sheel Shoe Explodes	Vecuum Stability Test: cc/40 Hrs, at
Fiber Shoe Explodes	90°C
0.00	100°C Explodes
Rifle Bullet Impact Test: Trials	120°C
% Explosions	135°C
Portiols	150°C
Burned	200 Grem Bemb Sand Test:
Unaffected	Sand. am
Explosion Yemperature: *C	
Seconds, 0.1 (no cop used) 263	Sensitivity to Initiation: Minimum Detonating Charge, gm
1 239	Mercury Fulminate
Explodes 210	Lead Azide
199	Tetryl
15 194	
20 190	Ballietic Mertar, % TNT:
75°C International Heat Test:	Trouxi Test, % TNT: (a) 51
% Loss in 48 Hrs 0.18	Plate Dent Test:
	Method
100°C Heet Test: Exploded in 16 hours	Condition
% Loss, 1st 48 Hrs	Confined
% Loss, 2nd 48 Hrs	Density, gm/cc
Explosion in 100 Hrs	Brisonce, % TNT
Flammebility Index:	Detenation Rate:
resume surprise and the	Confinement
Hygrescepicity: % 30°C, 90% RH 0.02	Condition Pressed
	Charge Diameter, in.
Veletility:	Density, gm/cc 2.0 3.0 4.0
-	Rate, meters/second 3500 4250 5000

Mercury Fulminate

Fregmentation Test:	Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile, Let WC-91:	Glass Cones Steel Cones
Density, gm/cc	Hole Volume
Charge Wt, Ib	Hole Depth
Total No. of Fragments:	Celer: White to gray
For TNT	111111111111111111111111111111111111111
For Subject HE	Principal Uses: Detonators and ingredient of
3 inch HE, M42A1 Projectile, Let KC-5:	priming compositions
Density, gm/cc	
Charge Wt, Ib	
Total No. of Fragments:	Method of Londing: psi x 10 ³
For TNT	3 5 10 12 15 20
For Subject HE	3-00 3.20 3.60 3.70 3.82 4.00
	Leading Dansity: gm/cc
Fregment Velocity: ft/sec	
At 9 ft	
At 251/2 ft	Storage:
Density, gm/cc	Method Wet
Bleet (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9
Air:	Compatibility Group Group M (wet
Peak Pressure	
Impulse	Exudation None
Emergy	
Air, Confined:	Stab Sensitivity:
Impulse	Density Firing Point (inch-ounces)
•	gm/cc 04 504 1004
Under Water:	3.91 3.2 4.3 5.5 4.26 1.6 2.6 5.5
Peak Pressure	1.32 1.6 2.6 4.0
Impulse	4.50 1.6 2.5 4.0
Energy	Activation Energy:
	kcal/mei 29.81
Undergreund: Peak Pressure	Induction Period, sec 0.5-10
Impulse	Heat of:
	Combustion, cal/gm 938 Explosion, cal/gm 427
Energy	Gas Volume, cc/gm 243
-	Formation, cal/gm -226
	Formation, cal/gm -226
	Specific Heat: cal/gm/°C 1.1
	, , , , , , , , , , , , , , , , , , , ,

Mercury Fulminate

Initiating Efficiency; Grams Required to Give Complete Initiation of:

Fulminate, gm

TNT	0.25
Tetryl	0.20
RDX	0.19
PETE	0.17

Compatibility with Metals:

Dry: Reacts rapidly with aluminum and magnesium. Reacts slowly with copper, zinc, brass and bronze. Iron and steel are not affected.

Wet: Reacts immediately with aluminum and magnesium. Reacts rapidly with copper, zinc, brass and bronze. Iron and steel are not affected.

Sensitivity to Static Discharge, Joules: (b)

0.025

The Effect of Storage at 50°C (Dry) on the Purity of Mercury Fulminate

1	ecrystall:	ized Lots	Uncrystallized Lots		
272	980	981	<u>982</u>	505.6-7/31	505.3-5/11
99-75	99-77	99-79	99.79	98.86	98.7
∳\$1 3 6	99.45	99.54	99.47	95-95	98.7 97.4
				94.95	94.9
98.74 98.26 98.22	99.56	97.49	99.06 98.79	90.65	
97.52 97.00	99.30 98.66	99.30 99.01	98.19 97.75 96.69	83.76	
94.81	98.58	98.45	95.90	79.99 74.52 63.80	
	99.75 99.75 98.74 98.26 98.22 97.52 97.50 95.70	99.75 99.77 99.75 99.77 99.36 99.45 98.74 99.56 98.26 98.26 98.22 97.52 99.30 97.00 95.70 98.66	99.75 99.77 99.79 95.36 99.45 99.54 98.74 99.56 97.49 98.26 98.22 97.52 99.30 99.30 97.00 99.01 95.70 98.66	99.75 99.77 99.79 99.79 99.75 99.45 99.54 99.47 98.74 99.56 97.49 99.06 98.26 98.79 98.22 97.52 99.30 99.30 98.19 97.00 99.01 97.75 95.70 98.66	979 980 981 982 505.6-7/31 99.75 99.77 99.79 98.86 95.36 99.45 99.54 99.47 95.95 94.95 94.95 94.95 94.95 98.74 99.56 97.49 99.06 90.65 98.26 98.79 98.79 98.79 96.22 97.52 99.30 98.19 83.76 97.00 99.01 97.75 95.70 96.69 94.81 98.58 98.45 97.90 79.99 74.52

Chemistry:

Mercuric fulminate readily decomposes in the presence of aqueous solutions, chlorides, carbonate and many other materials. Due to the presence of small amounts of mercury, formed by exposure to light or elevated temperatures, it readily forms amalgams with copper, brass and bronze, thus components containing these metals must be protectively coated if used with fulminate.

Solubility, Grams of Mercury Fulminate in 100 Grams of Water (%):

<u>°c</u>	至
12	0.07
49	0.18

Preparation:

(Chemistry of Powder and Explosives, Davis)

$$CH_3 - CH_2 - OH \longrightarrow CH_3 - CHO \longrightarrow CH_2 - CHO \rightleftharpoons CH - CHO$$

$$H \longrightarrow H_0 OH$$

$$N - OH$$

Five gm mercury is dissolved in 25 cc of nitric acid (sp gr 1.42) without agitation, and this solution poured into 50 cc of 90% ethyl alcohol, resulting in a vigorous reaction, attended by evolution of white fures and subsequent appearance of fulminate crystals. Red fuses then appear as precipitation of the product accelerates, and then white fuses again are evolved as the reaction moderates. After about 20 minutes the reaction is over; water is added, and the crystals are repeatedly washed, by decentation, with veter to remove all acidity. The product is purified, rendered white, by solution in strong ammonium hydroxide, followed by reprecipitation with 30% acetic acid.

Origin:

Mercury fulminate was first prepared by John K. von Lowenstern (1630-1703) and in 1800 its preparation and properties were first described in detail by Edward Howard in a paper presented to the Royal Society of London (Phil Trans, 204 (1800). It was 1867 before the compound was used as an initiating agent, when Alfred Nobel invented the blasting cap and used mercury fulminate to detonate nitroglycerin (British Patent 1345 (1867)).

Destruction by Chemical Decomposition:

Mercury fulminate is decomposed by adding it, while stirring, to at least 10 times its weight of 20% sodium Chiosulfate. Some poisonous cyanogen gas may be evolved.

References: 43

- (a) Fh. Macum Z ges Schiess-Sprengstoffw (Munich), pp. 181, 229, 267 (27 June 1932).
- (b) F. W. Brown, D. H. Kusler, and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

⁴³See footnote 1, page 10.

ercury Fulminate

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(c)	Also see	the	following	Picatinny	Arsenal	Techni	cal Re	orts on	Mercury	Fulminate:
	<u>o</u>	1	2	<u>3</u>	4	2	<u>6</u>	I	<u>8</u>	2
	250 480 510 550 610 660 760 1220 1450	301 381 561 1651	132 452 582 582 782 882 932 11352 1372 1722 2032	23 203 393 433 833 1183 1393 2093	144 294 534 624 694 784 874 1104	65 105 255 285 365 415 425 1325 1365	266 366 556 566 865 986 1316 1486 1556 2146	277 297 407 537 567 637 857 1737	28 78 278 318 788 1836	199 609 749 849 999 1079 1389 2179

AMCP 706-177 Metriol Trinitrate (MTN) Liquid (or Trime+hylolethane Trinitrate)

Composition:	Molecular Weight: (C-H9N309)	255
% C 23.5 O ₂ NO—CH ₂	Oxyge Belence: CO ₂ % CO %	-35 - 3
H 3.5 O_2NO-CH_2 $C-CH_3$ N 16.6 O_2NO-CH_2	Density: gm/cc Liquid	1.47
0 56.4 0 ₂ NO-CH ₂	Molting Point: *C	-3
0 56.4 ² ² C/H Ratio 0.150	Freezing Point: *C	· · · · · · · · · · · · · · · · · · ·
Impact Sonsitivity, 2 Kg Wt:	Boiling Point: *C	
Bureau of Mines Apparatus, cm 47; (1 1b wt) 4 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 20	Refrective Index, n ¹¹ ₂₀ n ⁰ ₂₀	1.4752
Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe	Vecuum Stability Test: cc/40 Hrs, at 90°C	
Rifle Bullet Impact Test: Trials	100°C cc/gm / 1.9	
% Explosions	135°C	
Partials	150°C	
Burned	200 Grem Bomb Sand Test:	
Unaffected	Sand, gm	¹ 43.7
Explosion Temperature: °C Seconds, 0.1 (no cop used) 1 5 Ignites 235	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
15 20	Ballistic Morter, % TNT: (a)	136
	Trouzi Test, % TNT: (b)	140
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	
100°C Heat Test:	Condition	
% Loss, 1st 48 Hrs 2.5	Confined Density, gm/cc	
% Lrss, 2nd 48 Hrs 1.8 Explosion in 100 Hrs None	Brisonce, % TNT	
Flemmebility Index:	Detenation Rate: Confinement Condition	
Hygrescepicity: % 30°C, 90% RH 0.07	Charge Diameter, in.	
	Density, gm/cc	

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:			
% mm HE, M71 Projectile, Let WC-91:	Glass Cones	Stret Cones		
Density, gm/cc	Hole Volume			
Charge Wi, ib	Hole Depth			
Total No. of Fragments:	Color: Oilv.	-14-14-2		
For TNT	Orly,	slightly turbid		
For Subject HE	Principal Uses: Ingredient of	of rocket and		
3 inch HE, M43A1 Projectile, Let KC-5:	double base	propellants		
Density, gm/cc				
Charge Wt, Ib				
Total No. of Fragments:	Method of Looding:			
For TNT				
For Subject HE	Leading Density: gm/cc			
Programm Velocity: ft/sec	- State of the sta	÷.		
At 9 ft At 25½ ft	Steroge:			
Density, gm/cc	Method	Liquid		
Flust (Relative to TNT):	Hazard Ckss (Quantity-Dista	nce)		
Air:	Compatibility Group			
Peck Pressure				
Impulse	Exucation			
Energy:				
Air, Cenfined: Impulse	Solubility in Water, gm/100 gm, at:			
	25°C 60°C	< 0.015		
Under Weter: Peak Fressure	60°C	<0.015		
Impulse	Heat of:			
Energy	Combustion, cal/gm	2642		
Underground:	Hydrolysis, % Acid:			
Pecik Pressure		A 43.0		
Impulse	10 days at 22°C 5 days at 60°C	0.018 0.115		
Energy	22,5 20 30 0	U-11)		

Metriol Trinitrate (MTN) Liquid

Preparation:

Metriol (trimethylolmethylmethane) is obtained by the following procedure, based on work by flosseus (Annalen 276, 76 (1893):

Into a 5 liter round bottom flask is weighed 2700 gms of water. To this are added 267 gms of 36% formaldehyde and 60 gms of propionaldehyde. The mixture is stirred for a few seconds. To the mixture is added 150 gms of calcium oxide previously slaked with 600 gms of water. The mixture is heated in boiling water for four hours, and then allowed to cool spontaneously overnight. After filtering off the insoluble calcium hydroxide, the solution is heated and treated with a saturated aqueous solution of oxalic acid to precipitate all the calcium. The precipitated calcium oxalate is filtered off, and the pale-yellow filtrate concentrated as much as possible on the steam bath to a thick lemon-yellow syrup. After dissolving in absolute alcohol, the solution is filtered and concentrated in the steam bath to about twice the volume of the concentrated syrup. The solution is then chilled in a cold box to hasten crystallization. After allowing it to warm up to just above 0°C, the mixture is filtered. The resulting product is not sufficiently pure and is recrystallized from absolute alcohol. The melting point of the product (40.3 gm) is then about 196°C (Hosseus gives 199°C).

Metricl is nitrated by cerefully mixing it with 3.5 parts of 65/35 HNO₂/H₂SO₃ maintained at 20°C, stirring for 30 minutes, cooling to 5°C, and pouring the reaction mixture on ice. It is extracted with ether, water-washed, and adjusted to pH 7 by shaking with 3 sodium bicarbonate solution and again water-washed three times. It is then dried with calcium chloride, filtered, and freed of ether by bubbling with dry air until minimal rate of loss in weight is attained. The yield is 88% of the theoretical. The product has a nitrate-nitrogen content of 16.35% (calculated: 16.47%). Its refractive index at 25°C is 1.4752.

Origin:

MIN, according to Italian sources, was first prepared and patented by Bombrini-Parodi-Delfino Company of Italy under the name "metriolo." A German Patent of 1927 also describes the preparation and gives some properties. This compound was known in France before World Wax II under the name of "Nitropentaglycerin" and Burlot and Thomas determined its heat of combustion (Ref b).

References: 44

- (a) A. H. Blatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.
 - (b) E. Burlot and M. Thomas, Mem poudr 29, 262 (1939).
- (c) Also see the following Picatinny Arsenal Technical Reports on Metriol Trinitrate: 1616 and 1817.

⁴⁴See footnote 1, page 10.

Melecular Weight:	n	
Cxygen Belence:		
	-38	
CO 48	-20	
Density: gm/cc	1.62-1.68	
Melting Faint: 'C		
Freezing Point: *C		
Soiling Point: °C		
Refrective Index, no		
n _m		
ng.		
Vacuum Sephiller Tass	Petrological	
· -		
90°C		
100°C		
120°C	2.1	
135°C		
150°C		
200 Georg Rough Sand Touts		
Sond, gm		
Sensitivity to Initiation:		
Minimum Detonating Charge,	, gm	
Mercury Fulminate		
Lead A zide		
Tetryi		
Beilistic Marter, % TNT: (a)	143	
	В	
	Pressed	
= = ==	No No	
I	1.73	
, , , , , , , , , , , , , , , , , , ,	66	
(-)	Non e	

Charge Diameter, in.	Cast. 1.6	
	1 - [1	
Density, gm/cc	1.68	
	CO. % CO % Density: gm/cc Melting Faint: "C Freezing Point: "C Refrective Index, no	

Pressed 100 1.46	Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol)
	Heat, kilocalorie/mole
1.45	(AH, kcgi/mol)
	N Company of the Comp
	Temperature Range, *C
1.74	Phase
(f)	Armor Plate Impact Test: (1)
•	
1050	60 mm Morter Projectile:
	50% Inert, Velocity, ft/sec 828
	Aluminum Fineness
	500-16 General Purpose Bembs:
	Plate Thickness, inches
_	ויייניין די דיייניין די דיייניין די דיייניין די דיייניין די דיייניין דייניין דיינייין דיייין דייניין דייניין דייניין דייניין דיינייין דיינייין דייניין דייין דיינייין דייניין דייניין דייניין דיינייין דיייין דיינייין דיייין דיייין דיינייין דייייין דייייין דיינייין דייניין דיינייין ד
1.74	1
	134
	11/4
	124
	Somb Drop Test:
16.5 x 10 ⁻¹	17, 2000-lb Semi-Armor-Piercing Bemb vs Concrete:
1.74	
	Sax Safe Drop, ft
	500-le General Purpose Bemb vs Concrete:
	Heigh*, ft
	Trials
	Unaffected
	Low Order
10	High Order
6	
-	1000-lb General Furpose Bomb v3 Concrete:
1.66	11.15.6
1910-2070	Height, ft Trials
	Unoffected
	== {
	Low Order
	High Order
	₹
	0.30 1.74 (b) 16.5 x 10 ⁻¹ 1.74

Minol-2

Glass Cones Steel Cones Hole Volume Hole Depth Celor: Gray Principal Uses: Bombs and depth charges Method of Leeding: Cast
Hole Volume Hole Depth Celer: Gray Principal Uses: Bombs and depth charges Method of Leeding: Cast
Color: Gray Principal Uses: Bombs and depth charges Method of Leeding: Cast
Principal Uses: Bombs and depth charges Method of Leeding: Cast
Principal Uses: Bombs and depth charges Method of Leeding: Cast
Method of Leeding: Cast
Method of Leeding: Cast
Applica Baseline and see 1 60 1 68
Storege:
Method Dry
Hazard Class (Quantity-Distance) Class 9
Compatibility Group Group I
Exudation
Preparation:
Minol is a castable mixture consisting of
40 percent TNT, 40 percent ammonium nitrate.
and 20 percent powdered aluminum and there- fore can be prepared by adding the dry in-
gredients to molten TNT at 90°C under agita-
tion. Minol also can be prepared by adding 25 parts of aluminum to 100 parts of 50/50
amatol previously prepared.

Origin:

Minols are British ternary explosives developed during World War II. There are three formulations:

Composition, 5:	Minol-1	Minol-2	Minol-3
TMT	48	40	42
Ammonium Nitrate	42	40	3 8
Aluminum	10	20	20

References: 45

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Emplosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1975.
- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
 - (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.
- M. D. Hurwitz, The Nate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.
- (e) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, MOL Memo 10,303, 15 June 1949.
 - (f) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.
- (g) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Technical Mv Lecture, 9 April 1948.
 - (h) Also see the following Picatinny Arsenal Technical Reports on Minol-2: 1585 and 1635.

⁴⁵See footnote 1, page 10.

Composition:		Melecular Weight:	40.6
% Oxidizing apent (Armonium		Oxygen Belence:	
Perchlorate)	35.0	CO. %	-44
Aluminum, atomized	26.2	CO %	-37
Cupric Oxide			
Magnesium, atomized	26.2	Density: gm/cc Pres	sed 2.0
Other ingredient (Tetryl)	9.7		
Calcium Stearate	1.9 1.0	Melting Point: °C	
Graphite, artificial C/H Rotio	1.0	Freezing Point: *C	
Impact Soncitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm			
Sample Wt 20 mg		Refrective Index, no	
Picatinny Arsenal Apparatus, in.	13	n <u>s</u>	
Sample Wt, mg	22		
		n 🙀	
Friction Pendulum Test:		Vocuum Stability Test:	
Steel Shoe	Detonates	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
		— 100°C	0.47
Rifle Sulfat Impact Test: Trials		120°C	
%		135°C	
Explosions		150°C	
Partials		150°C	
Burned		200 Grem Bomb Sand Test:	
			10.6
Unaffected	· · · · · · · · · · · · · · · · · · ·	Sand, gm	
Explosion Temperature: 'C		Sensitivity to Initiation:	
Seconds, Q.1 (no cop used)		Minimum Detonating Charge, gr	n
1		Mercury Fulminate	
5 285		Leod Azide	0.20
10		Tetryi	0.25
15		l esry:	
20		Sallistic Merter, % TNT:	
		Treuzi Test, % TNT:	
75°C International Hos? Test:		Plate Dent Test:	
% Loss in 48 Hrs Discoloration, fumes, odor	None	Method	
	-14-14	Condition	
100°C Heat Yest:			
% Loss, 1st 48 Hrs	0.10	Confined	
% Loss, 2nd 48 Hrs	0.01	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
		Detonation Rate:	
Flammability Index:		Confinement	
Hygrescopicky: %		Condition	
TITEL TO		Charge Diameter, in.	
Volatility:		Density, gm/cc	

Fregmentation Test:	Shaped Charge Effectiveness, TNT = 10	0:
90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Co Hole Volume Hole Depth	pnes
Total No. of Fragments: For TNT	Color: Gray powder mixture	
For Subject HE 3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, lb	Principal Uses: Small caliber ant: projectiles	laircraft
Total No. of Fragments: For TNT	Method of Loading:	Pressed
For Subject HE Fregment Velocity: ft/sec	Leeding Deasity: gm/cc At 30,000 psi	~ 2.0
At 9 ft At 25½ ft Density, gm/cc	Sterege: Method	Dry
liest (Relative to TNT):	Hazard Class (Quantity-Distance)	Class 9
Air: Peak Pressure Impulse Energy	Compatibility Group Bureau of Explosives Classific Exudation	Group I cation Class A
Air, Confined: Impulse Under Weter: Peak Pressure Impulse	Heat of: Combustion, cal/am Explosion, cal/gm Gas volume, cc/gm Performance Tests:	4087 2087 212
Energy Underground: Peak Pressure	20 mm T215El Projectile: NFOC Pressure Cube APG Blast Cute Activation Energy:	35 40

Composition:		Molecular Vielght:	42
Oxidizing agent (Ammonium Perchlorate) Aluminum, atomized	35.0 52.4	Oxygen Belence: CO ₂ % CO %	-4 ? -43
Cupric Oxide Magnesium, atomized		Density: gm/cc Pressed	2.0
Other ingredients* Calcium Stearate	9.7 1.9	Molting Point: *C	
Graphite, artificial *5.8% RMX and 3.9% TNT coated po	1.0 n Appropium	Freezing Point: °C	
Impact Sensi wity, 2 Kg Wt:	cinora ce.	Beiling Point: °C	
Bureau of Mines Apparatus, cm Sample Wt 20 mg		Refrective Index, no	
Picatinny Arsenal Apparatus, in.	12	n _m	
Somple Wt, mg	24	n _{ss}	
Friction Pondulum Test:		Vacuum Stability Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
Rifle Bullet Impact Test: Trials		100°C	0.21
·		120°C	
% Explosions		135°C	
Portials		150°C	
Burved		200 Gram Bomb Sand Test:	
Unoffacted		Sand, gm	11.5
Explosion Temperature: *C Seconds, 0.1 (n. csp used)		Sensitivity to Initiation: Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5 375		Lead Azide	0.20
10		Tetryl	0.20
15			
20		Ballistic Morter, % TNT:	
73°C International Heat Test:		Trougi Test, % TNT:	
% Loss in 48 Hrs Discoloration. fumes, odor	None	Plate Dest Test: Method	
100°C Heet Test:		Condition	
% Loss, 1st 48 Hrs	0.27	Confined	
% Loss, 2nd 48 Hrs	0.12	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TN1	
Flammability Index:		Detenation Rate: Confinement	
Hygruscopicity: %		Condition Charge Diameter, in.	
Veletility:		Density, gm/cc Rate, meters/second	

Fragmentativa Test:			Shaped Charge Effectiveness, TNT = 100:		
90 mm HE, M71 Projectil Density, gm/cc Charge Wt, ib	e, Let WC-91	:	Glass Cones Steel Cones Hole Volume Hole Depth		
Total No. of Fragments: For TNT	:		Color:	Gray	
For Subject HE			Principal Uses: HE filler for small c	-145	
3 inch HE, M42A1 Project Density, gm/cc Charge Wt, Ib	ile, Let KC-5	:	projectiles	atioar	
Total No. of Fragments: For TNT			Method of Loeding:	Pressed	
For Subject HE			Leeding Density: gm/cc	2.0	
Fragment Velocity: ft/sec At 9 ft At 251/2 ft			Storage:	·	
Density, gm/cc			Method	Dry	
Blast (Relative to TNT):			Hazard Class (Quantity-Distance)	Class 9	
Air: Bare Charge:	EW*	EV# 1.34	Compatibility Group Bureau of Explosives Class A	Group I	
Impulse	1.08	1.41	Exudation	None	
Energy Density, gm/cc Air, Conflact: Impulse		1.96	Heat of: Combustion, cel/gm	fr:8#	
Cased Charge in Air:*	*		Explosion, cal/gm Gas volume, cc/gm	14,72 22	
Peak Pressure Impulse	1.09 1.16	1.44 1.53	Performance Tests:		
Energy Density, gm/cc		1.98	20 mm T215E1 Projectile:	29	
Underground: Peak Pressure			APG Blest Cube	30	
impulse			Aviation Energy:		
*EW, equivalent weight EV, equivalent volume			kcel/mol Temp, CC 340 Time to ignition, seconds 1.3	7.6 to 470 9 x 10 ⁻²	
**Strong paper-base phe	•				

Effect of Altitude, Charge Diameter and D. Gree of Confinement on Detonation Velocity* (Reference g)

	One-In	ch Column	Two-Inch	Column	
Simulated Altitude, Feet	Confined m/s	Unconfined m/s	Confined m/s	Unconfined m/s	
Cround			4730		
30,000	Charge would not		90,000 Charge would not 4530(3)	4530(3)	Charge wou
60,000	propugate	detonation.	14430	not propa- gate detona-	
90,000	•		4290	tion.	
Average	•		4495		

^{*}Confined charge in 1/4" steel tube. AISI 1015 seemless, 1" diameter 18" long, and 2" diameter 7" long. All means were determined from sets of five values unless otherwise indicated by (). A 26 gm tetryl booster was used to initiate each charge.

Average Fragment Velocity at Various Altitudes* (g)

	1	Sin			t
Explosive	Charge Diameter,	Ground	30,000	60,000	<u>; 90,000</u>
	Inches	m/s	m/s	m/8	.√s
MOX-2B, density,	1	2012	**	**	**
gm/cc 207	2	3314	3351	3247	**

^{*}Outside diameter 2.54"; inside diameter 2.04"; length 7".

^{**}Charge would not propagate detonation.

Composition:		Melecular Weight:	45.6
Oxidizing agent (Potassium Ni	trate) 18	Oxygen Belence:	
Aluminum, atomized	5 0	CO. %	-52
Cupric Cxide Magnesium, atomized		CO %	-52 -43
Other ingredients*	32		
Culcium Stearate**	2.0	Density: gm/cc Pressed	2.0
Graphite, artificial**	1.0	Melting Point: °C	
*29.1% RDX, 0.9% wax, and 2. **Per cent added.	0% TNT.		
		Freezing Point: *C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	••	Boiling Point: *C	
Sample Wt 20 mg	17	Refrective Index, no	
Picatinny Arsena! Apparatus, in. Sample Wt, mg	17 24	n _R	
Sumple Wt, mg	24	ກລື	
Friction Pendulum Test:		Vocuum Stebility Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
		- 100°C	0.57
Rifle Bullet Impact Test: Trials		120°C	2.51
96			
Explosions		135°C	
Partials		150°C	
Burned		200 C P C 4 T 1	
Unaffected		200 Grem Bomb Sand Tost:	
Ungrected		Sand, gm	33.2
Explosion Temperature: 'C		Sensitivity to Initiation:	
Seconds, 0.1 (no cop used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5 540		Lead Azide	0.20
10		Tetryi	0.15
15		Belli .: Morter, % TNT:	
20		Trougi Test, % TNY:	
75°C International Host Test:		Plate Dent Test:	
% Loss in 48 Hrs Discoloration, fumes, odor	None	Method	
	110116	Condition	
100°C Heat Test:	0.35	Confined	
% Loss, 1st 48 Hrs	0.35	Density, gm/cc	
% Loss, 2nd 48 Hrs	0.13		
Explosion in 100 Hrs	None	Brisance, % TNT	
Flammability Index:		- Detenation Rate: Confinement	
Hygrescopicity: %		- Condition	
, g		Charge Diameter, in.	
Veletility:		Density, gm/cc	

Fregmentation Test:	Shaped Charge Effectiveness, TNT == 100:		
90 mm HE, M71 Projectile, Let WC-91:	Glass Con	es Steel Cones	
Density, gm/cc	Hole Volume		
Charge Wt, Ib	Hole Depth		
Total No. of Fragments:	Color: Gi	ray powder mixture	
For TNT	Com: 0.	ay powder mixture	
For Subject HE	Principel Uses: Small ca	aliber antimircreft	
3 inch HE, M42A1 Projectile, Let KC-5:	projecti	les	
Density, gm/cc			
Charge Wt, Ib			
Total No. of Fragments:	Method of Leading:	Pressed	
For TNT		110000	
For Subject HE			
	Looding Density: gm/cc		
Fragment Velocity: ft/sec	At 30,000 psi	~2.0	
At 9 ft At 25½ ft	Storage:		
Densit/, gm/cc			
	Method	Dry	
Blast (Relative to TNT):	Hazard Class (Quantity-I	Distance) Class 9	
Air:	Compatibility Group	Group I	
Peak Pressure	Bureau c	of Explosives Class A	
Impulse			
Energy			
Air, Confined:	Heat of:		
Impulse	Combustion, cal/gm	ı 4331	
44 4 344 .	Explosion, cal/gm		
Under Weter: Peak Pressure	Gas volume, cc/g	gm 232	
Impulse	Performance Tests:		
Energy	20 mm T215El Proje	ctile:	
Undergreund: Peak Pressure	NFOC Pressure Cube APG Blast Cube	37 52	
Impulse	Activation Energy:		
Energy			
- -	kcal/mol Temp, C	Values not included	
	Temp, C Time to ignition,	due to erratic ig- nition under condi-	
	seconds	tions of test.	

Composition:		Melecular Weigin:	F 8
Oxidizing agent (Barium Nitret Aluminum, atomized Cupric Oxide Magnesium, atomized	18 50 	Oxygen Belence: CO ₂ % CO %	-53 -43
Other ingredients* Calcium Stearate**	32 2.0	Density: g: //cc Pressed	2.0
Graphite, artificial** *29.1% RDX, 0.9% wax, and 2.0 **Per cent added.	1.0 d TNT.	Malting Point: "C Freezing Point: "C	
Impact Scasitivity, 2 Kg Wt:	-0	Boiling Point: °C	
Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	78 18 26	Refrective Index, no	
Friction Pendulum Yest: Steel Shoe Fiber Shoe	Sparks Unaffected	Vecuum Stability Test: cc/40 Hrs, at 90°C	
Rifle Bullet Impact Test: Trials Explosions Partials		100°C 120°C 135°C 150°C	0.67
Burned Unoffected		200 Grem Bomb Sand Test: Sand, gm	33.6
Explosion Temperature: *C Seconds, 0.1 (no cap used) 1 5 610	a a marin a ma	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide	0.20
15 20		Tetryl Bellistic Morter, % TNT:	0.15
75°C International Heat Test: % 1:3s in 48 Hrs Discoloration, fumes, odor	None	Plate Dent Test: Method	
180°C Heet Test: % Loss, ist 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	0.22 0.12 None	Condition Confined Density, gm/cc Brisance, % TNT	
Flammability index:		- Detenation Rate: Confinement	
Hygroucopicity: %		Condition Charge Diameter, in.	
Veletility:		Density, gm/cc Rate, meters/second	

MCX-4B

Fragmantstion Test:	Shaped Charge directiveness, TNT = 100:				
90 mm HE, M71 Prejectl > Let WC-91: Density, gm/cc	Glass Cones Hole Volume	Steel Cones			
Charge Wt, Ib	Hole Depth				
Total No. of Fragments: For TNT	Color:	Gray powder mixture			
For Subject HE 3 inch HE, M42A1 Project Let XC-3: Density, gm/cc Charge Wt, Ib	Principal Usa: Small caliber entiaircraft projecules				
Total No. of Fragments: For TNT For Sub, act HE	Merhod of Localing:	Pressed			
Fragment Velocity: ft/sec	Leeding Density: gm/cc At 30,000 psi	~ [/ 0			
At 9 ft At 251/ ₃ ft	Storage:				
Density, gm/cc	Method	Dies			
Blass (Relative to TNT):	Hozard Class (Quantity-Dis	tance) Class 9			
Air: Peak Pressure Impulse Energy	Compatibility Group	Group I Bureau of Explosives Class A			
Air, Confined: Impulse Lader Weter: Peak Pressure Impulse Energy	Commustion, cal/gm Explosion, cal/gm Gas volute, cc/gm Performance Tests: 20 mm T215E1 Project	4392 709 208 11e:			
Underground: Peak Pressure impulse	NFOC Pressure Cube APG Blast Cube Aviation Energy:	43 53			
Energy	kcel/mol Temp, C Time to ignition, seconds	Values not included due to erratic ignition under conditions of test.			

Composition:		Molecular Weight:	43
Oxidizing agent		Oxygen Belence:	
Aluminum, atomized	49.2	CO. %	50
Cupric Oxide	19.7	CO %	-50 -42
Magnesium, at mized			-42
Other ingredients*	29. 6	Density: gm/cc	
Calcium Stearate			
Graphite, artificial	1.5	Melting Point: °C	
*28.7% RDX coated, 0.9% wax.			
C/H Ratio		Freezing /oint: *C	
Import Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm	78		
Sample Wt 20 mg		Refractive Index, no	
Picatinny Arsenal Apparatus, in.	19		
Sample Wt, mg	27	n _S	
		i n ₂₀	
Friction Pendulum Test:		Vacuum Stebility Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaifected	90°C	
		100°C	0.43
Rifle Bullet Impact Test: Tricls			0.43
%		120°C	
Explosions 70		135°C	
Portials		150°C	
Burned			
		200 Gram Bomb Sand Test:	
Unaffected		Sand, gm	10. 8
Explosion Temps ature: 2C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, ym	
1			
5 510		Mercury Fulininate	
- /10		Lead Azide	0.20
10		Tetryi	0.16
15		Bellinia Manage W. 11/2	
20		Sallistic Morter, % 167:	
75°C International Heat Test:		Trauzi Test, % TNT:	
Loss in 48 Hrs	0.02/10 gm	Flate Dent Test:	
Discoloration, fumes. odor	None	Method	
109°C Heat Test:		Condition	
% Loss, 1st 48 Hrs	0.00	Confined	
Co Loss, 2nd 48 Hrs	0.00	Density, gm/cc	
•		Brisance % TNT	
Explosion in 100 Hrs	None		
		Detenation Rate:	
Flammahility Inday			
Flammability Index:		Confinement	
		Condition	
Tygroscopicity: %	0.79		
	0.79	Condition	

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MOX-6B

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:				
90 mm HC, M71 Projectile, Lct WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments:	Glass Cones Steel Cones Hole Volume Hole Depth				
For TNT For Subject HE	Color: Gray powder mixture				
3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: Small caliber antiaircraft projectiles				
Total No. of Fragments: For TNT	Method of Leading: Pressed				
For Subject HE Fregment Velocity: ft/sec At 9 ft At 25½ ft	Looding Density: gm/cc At 30,000 psi ~2.0 Storage:				
Density, gm/cc	Method Dry				
Black (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9				
A ir: Peak Pressure Impulse Energy	Compatibility Group Grop I Bureau of Explosives Class A				
Air, Confined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Combustion, cal/gm 4293 Explosion, cal/gm 750 Gas volume, cc/gm 204 Activation Energy: kcal/mol Values not included temp, C due to erratic ignitime to ignition, seconds of test.				

MOX-1; MOX-2B; MOX-3b; MOX-4B; MOX-6B

Preparation:

The various ingredients used in the preparation of MOX explosives are coated separately as follows:

Dichromated Atomized Aluminum - Seventy-five grams of chemically pure grade sodium dichromate is dissolved in 1500 milliliters of water at 100°C under mechanical agitation. Six hundred grams of the atomized aluminum powder is added gradually (2 to 3 minutes) and stirring is continued for half an hour. The dichromated metal is filtered, washed with water (15 to 20 times) until the washings show only a slight cloudiness with silver nitrate. The water-wet product is then dried in an oven at 50°C. The dried material is hand-rolled to reduce any conglomerates, and blended before use.

Wax-Coated RDX - Eighteen grams of molten Be Square Special Wax (manufacturer : 180° to 185° Fahrenheit grade amber) is added to 582 grams of finely divided RDX (water precipitated from acetone solution) in a water slurry under mechanical agitation. The temperature of the wax-RDX slurry is maintained above the melting point of the wax (about >0°C). The stirring is continued for half an hour. After cooling to 50°C, the wax-coated RDX is recovered by filtration in a Büchner funnel and dried in air. The RDX thus coated and presumed to be 3% waxed RDX or a 97/3 RDX/wax mixture is hend-rolled to crush any conglowerates formed, and bleuded by hand before use.

INT-Coated Barium Nitrate - Thirty grams of INT in alcohol solution is added to 270 grams of barium nitrate in an alcohol slurry under sgitation. The temperature of the INT-barium nitrate mixture is maintained at 80°C and stirring is continued until most of the alcohol is evaporated. The coated material is spread in a thin layer on a tray to dry in air overnight. The barium nitrate thus coated with 10% INT is reduced to an intimate mixture by hand-rolling and blending before use.

INT-Coated Potassium Nitrate - The INT-coated potassium nitrate is prepared by the same procedure as is used for coating barium nitrate.

ADX/INT-Coated Ammonium Perchlorate - The ammonium perchlorate is coated by dissolving the appropriate weights of RDX and INT in hot; cohol. After add. the ammonium perchlorate, the ivery is stirred until most of the solvent is evaporated. The treated ammonium perchlorate spread on a tray to dry overnight. Agglomerates formed during the process are crushed by band-rolling and blending the mixture before use.

TMT-Coated RDX - Sixty grams of rolten TMT are added to a water slurry of 540 grams of finely divided RDX (water precipitated from acetone solution) under mechanical agitation. The temperature of the TMT-RDX slurry is maintained at about 90°C and stirring is continued for helf an hour. After cooling to about 50°C, the TMT-coated RDX is recovered by filtration. The RDX thus treated, and presumed to be 10% coated or a 90/10 RDX/TMT mixture, is further blended by hand after rolling to crush any aggregates formed during the process.

The MOX explosive mixtures are prepared by blending the appropriate weights of the dry ingredients in a Patterson-Kelly twin-shell blender for at legst 30 minutes.

Origin:

MOX type explosive mixtures were developed beginning in 1950 by National Northern, technical division of the National Fireworks Ordnance Corporation, West Hanover, Massachusetts.

References: 46

- (a) A. O. Mirerchi and A. T. Wilson Development of MOX Explosives for Improved 20 mm Ammunition, Navy Contract Nord-10975, Task 1, National Fireworks Ordnance Corporation: First Yearly Summary, August 1950 to August 1951.
- (b) A. T. Wilson, Development of MOX Explosives: Various Oxidants in MOX, First Progress Report NFOC-6, Navy Contract Nord-12382, National Fireworks Ordnance Corporation, December 1952.
- (c) A. O. Mirarchi, Properties of Explosives: Theory of the MOX Explosion, First Progress Report NFOC-10, Navy Contract NOrd-11393, National Fireworks Ordnance Corporation, December 1952.
- (d) A. O. Mirarchi, Properties of Explosives, MOX Explosives in Various Atmospheres, First Progress Report NFOC-9, Navy Contract NOrd-11393, National Fireworks Ordnance Corporation, 1952.
- (e) A. T. Wilson, Development of MCX Explosives: Composition Variations, First Progress Report NFOC-7, Navy Contract NOrd-12382, National Fireworks Ordnance Corporation, 1952.
- (f) A. T. Wilson, <u>Development of MOX Explosives: Various Oxidants in MOX</u>, Second Progress Report NFOC-14, Navy Contract NOrd-13684, National Fireworks Ordnance Corporation, October 1953.
- (g) A. W. O'Brien, Jr., C. W. Plummer, R. P. Woodburn and V. Philipchuk, Detonation Velocity Determinations and Fragment Velocity Determinations of Varied Explosive Systems and Conditions, National Northern Corporation Final Summary Report NNC-F-13, February 1958 (Contract DAI-19-020-501-0RD-(P)-58).
- (h) P. Z. Kalanski, Air Blast Evaluation of MOX-2B Cased and Bare Charges, NAVORD Report No. 3759, 5 April 1956.
- (i) Also see the following Picatinny Arsenal Technical Reports on MOX Explosives: 1935, 1969, 2204. 2205.

⁴⁶See footnote 1, p.

Nitrocellulose, _2.6% (NC)

Composition:	Malecular Weight: (272.39)	1			
% C 26.46 H 2.78 N 12.60 X H X H	Orygen Falence: CO: % -35 CO % 0.6				
0 58.16 0 x	Density: gm/cc				
н	Melting Point: °C Decomposes				
C/H Ratio 0.23	Freezing Point: *C				
Impact Sensitivity, 2 Kg Wt: Rurenu of Mines Apparatus cm 8	Boiling Point: 'C				
Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 5	Refractive Index, no no no				
Friction Pendulum Test: Steel Shoe Filter Shoe	Vecuum Stability Test: cc/40 Hrs, at 90°C 0.17				
Rifle Bullut Impact Test: Trials % Explosions Partials	100°C 1.0 120°C 16 hours 11.+ 135°C 150°C				
Burned Unaffected	200 Grem Bomb Sand Test: Sand, gm 45.0				
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 170 10	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide O.10 Tetryl				
15 20	Ballistic Morter, % TNT:				
	Trouzi Test, % TNT:				
75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs	Plete Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT				
Explosion in 100 Hrs Flammability Index:	Detenotion Rete: Confinement				
Hygroscopicity: % 30°C, 90% RH 3	Condition Charge Diameter, in. Density, gm/cc				
Volatility: 60°C, mg/cm²/hr 0.0	Rate, meters/second				

Nitrocellulose, 13.45% N (NC)

emposition: H o	Melecular Weight:	(£86.34) _n
c 25.29	Oxygen Belance:	
H 2.52 R ₂ C	CO ₂ %	-29 4.7
N 13.45 X " H O " H	Density: gm/cc	
X=0NO ²	Melting Point: "C	Decomposes
C/H Ratio 0,23	Freezing Point: °C	
mpact Sensitivity, 2 Kg Wt:	Soiling Point: *C	
Bureau of Mines Apparatus, cm 9 Sample Wt 20 mg	Refrective Index, nº	
Picatinny Arsenal Apparatus, in. 3	n _s	
Sample Wt, mg 5	n _{so}	
Friction Pendulum Test:	Yecuum : 'Ility Test:	
Steel Shoe	cc/40 H.s, at	of ho
Fiber Shoe	90°C	0.42
Riffe Bullet Impact Test: Trials	100°C	1.5
%	120°C	11.+
Explosions	135°C	
Partials	150°C	
Burned	200 Gram Somb Sand Test:	
Unaffected	Sand, gm	49.0
Explosion Temperature: °C	Secusitivity to Initiation:	
Seconds, 0.1 (no cap used)	Minimum Detonating Charge	, sim
1 5 230	Mercury Fulininade	
10	Lead Azide	0.10
15	Tetryl	
26	Bellistic Morter, % INT:	125
	Trouzi Test, % TNT:	
75°C Internetional Heat Test: % Loss in 48 Hrs	Plate Dent Test:	
	Method	
1v0°C Heat Test:	Condition .	
% Loss, 1st 48 Irs 0.3	Confined	
% Loss, 2nd 48 Hrs 0.0	Density, gm/cc	
Explosion in 100 Hrs None	Brisance, % TNT	
Flommability Index:	Detenation Rate:	
	Condition	
Hygrescopicity: % 30°C, 90% RH ~ 2	Charge Diameter, in:	
Veletility: 60°C, mg/cm²/nr 0.0	Density, gm/cc	1.20

Composition:	Molecular Weight: (297-15) _n
% C 24.25 H 2.37 N 14.14 H 2 C H X	Oxygen Belence: CO ₂ % -24 CO % 6
0 59.24 0 H	Density: gm/cc 1.65-1.70
X n	Melting Point: °C Decomposes
C/H Ratio 0.23	Freezing Point: *C
Impact Sensitivity, 2 Kg Wt: Burgau of Mines Apparatus, cm 8	Boiling Point: °C
Sample Wt 20 mg	Refractive Index, 1120
Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 5	n 🖁
	n _{so}
Friction Pendulum Test:	Vocuum Stability Test:
Steel Shoe	cc/40 Hrs, at
Fiber Shor	90°C 1.46
Rifle Bullet Impact Test: Trials	
%	
Explosions	135 °C 150°C
Partials	157 C
Burned	200 Gram Bomb Sand Test:
Unaffected	Sand, gm 52.3
Explosion Temperature: °C	Sensitivity to Initiation:
Seconds, 0.1 (no cap used)	Minimum: Detonating Charge, gm
1	Mercury Fulminate
5	Leod Azide C-10
10	Tetryl
15 20	Bellistic Mortus, % TNT:
20	Trauxi Test, % TNT:
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test:
70 LOSS III 40 FIIS	Method
100°C Heat Test:	Condition
% Loss, 1st 48 Hrs	Confined
% Loss, 2nd 43 Hrs	Density, cm/cc
Explosion in 100 Hrs	Brisance, % TNT
	Detenation Rate:
Flammability Index:	Confinement
Hygroscopicity: % 30°C, 90% RH	Condition
Hygrescopicity: % 30°C, 90% RH ~ 1	Charge Diameter, in:
Voletility: 60°C, mg/cm²/hr 0.0	Density, gm/cc
	Rate, meters/second

Nitrocellulose (NC)

Fragmentation Test:	Sheped Charge Effectiveness, TNT = 100:			
90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc	Glass Cones Steel Cones Hole Volume			
Charge Wt, Ib	Hole Depth			
Total No. of Fragments:	Color:	White		
For TNT				
For Subject HE	Principal Uses: Pyroxylin			
3 inch HE, M42A1 Projectile, Let KC-5:		cellulose (12.60% N), guncotton (13.35% N		
Density, gm/cc	minimum), propell			
Charge Wt, ib	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,			
Total No. of Fragments:	Method of Looding:			
For TNT				
For Subject HE	Loading Density: gm/cc			
P. Common M. B. Charles				
Fragment Valuelty: ft/sec At 9 ft				
At 251/2 fr	Storuge:			
Density, gm/cc				
	Method	Wet (8% to 30% water)		
Bleet (Reletive to TNT):	Hozard Class (Quantity-Distance) Class 12			
Air:	Compatibility Group	Group M		
Peak Prescure	, - ,	(wet)		
Impulse	Exudation	None		
Energy				
Air, Confinct	Heat of:			
Impulse	Combustion, cal/gm 2409			
	Explosion, cal/gm 855 Cas Volume, cc/gm 919	5* 965 ** 1058 *** 5* 883 ** 853 ***		
Under Weter: Peak Pressure		* 561** 513***		
Impulse	* 12.6% N			
Energy	** 13.45% N *** 14.14% N			
Underground: Peok Pressure	Vapor Pressure:			
Impulse	°c	mm Mercury		
Energy				
~ '' Y	25 60	0.00		
	60	0.00		

Nitrocellulose (NC)

Solubility in Water, gm/100 gm, at:	12.6% N	13.45% N	14.0% N
25°C 60°C	Insoluble Insoluble	Insoluble Insoluble	Insoluble Insoluble
Solubility, gm/100 gm, 25°C, in:			
Ether Alcohol	Insoluble Very slight- ly soluble	Insoluble Practically insoluble	Insoluble Insoluble
2:1-Ether:Alcohol	Soluble	Slightly soluble (6%-11%)	Practically insoluble (1 + 2)
Acetone	Soluble	Soluble	Soluble
24)-Hour Hydrolysis Test, 5 Mitric Aci.	1.22	1.03	

Preparation of Nitrocellulose from Cotton Linters: (Imboratory Procedure)

Mitration: Second cut cotton linters, previously dried to a moisture content of less than 0.5%, are nitrated by immersion in mixed acid under the following conditions:

Ratio of Mixed Acid to cotton 55 to 1

Composition of Mixed Acid (approximate)

- a. for 12.6% N: H_2SO_4 63.5%, HNO_3 21%, H_2O 15.5%
- b. for 13.4% N: H₂SO₄ 68%, HNO₃ 22%, H₂O 10.0%

Temperature of acid at the start

34°C

Time of nitration

24 minutes

During the nitration period the mixture is turned over occasionally to keep the acid homogeneous. The mixture is then filtered on a Buchner funnel with suction for about three minutes and then drowned rapidly with strong hand stirring in at least 50 volumes of cold water. After the nitrocellulose has settled, most of the water is decanted and fresh water added. The nitrocell lose-water mixture is boiled and the acidity adjusted to 0.25% to 0.50% as $\rm H_2SOl_1$. The sour boil is continued for at least 24 hours for pyrocellulose and at least 40 hours for gun-cotton. Additional boiling with changes of water are made in accordance with the governing specification (JAN-N-244).

<u>Pulping:</u> The nitrocellulose is then pulped in a laboratory Holland type paper beater. Enough sodium carbonate is added to keep the reaction faintly alkaline to phenolphthalein. Pulping is continued to the desired degree of fineness.

Posching: After washing the nitrocellulose from the beater, the mixture is filtered and the product boiled for 4 hours with fresh water while stirring mechanically. From time to time a little codium carbonate solution is added to maintain the mixture faintly alkaline to phenolphtbalein. The water is decanted and the boiling continued. According to the specification, the total boiling treatment with poachi. is as follows:

Nitrocellulose (NC)

- 4 hours boiling with or without sodium carbonate
- 2 hours boiling without sodium carbonate
- 1 hour boiling without sodium carbonate
- 1 hour boiling without sodium carbonate.

Each boil is followed by settling and change of water.

Washing: The nitrocellulose is then washed by mechanical agitation with water. A minimum of two washes are given. If a sample taken after the water washes gives a minimum test of 35 minutes in the 65.5°C Heat Test and 30 minutes in the 134.5°C Heat Test, the nitrocellulose is satisfactorily stabilized. Otherwise additional washes should be given.

Origin:

Cellulose occurs in nature. It is wood fiber, cell wall and the structural material of all plants. Cotton fiber is pure cellulose. Nitrocellulose was discovered about 1847 by C. F. Schonbein at Basel id R. Bettger at Frankfort-on-the-Main independently of each other when cotton was nitrated. T. J. Pelouze had nitrated paper earlier (1838) and was probably the first to prepare nitrocellulose.

Pyroxylin or collodion, which is soluble in a mixture of ether and ethanol, contains from 8% to 12% nitrogen. It is used in the manufacture of celluloid and in composite blasting explosives.

Pyrocellulose, a type of nitrocellulose of 12.6% nitrogen content, comp. 'y soluble in a mixture of 2 parts ether and one part ethanol, was developed by Mendeleev (.1-1895). This material, when colloided, formed the first smokeleus powder for military use in the United States (1898).

Guncotton for military purposes they contains a minimum of 13.35% nitrogen. It is only slightly soluble in ether-ethanol, but completely soluble in acetone. Principal use is in flashless powders and as rlame carriers. 14.14% N nitrocellulose represents a theoretical limit.

In the manufacture of propellants, there is used a mixture of pyrocellulose and guncotton (blooded nitrocellulose) of 15.15% to 13.25% nitrogen content.

restruction by Chemical Decomposition:

Nitrocellulose is decomposed by adding it, with stirring, to 5 times its weight of 10% sodium hydroxide heated to 70°C. Stirring is continued for 15 minutes after all the nitrocellulose bas been added.

References: 47

(a) See the following Picatinny Argenal Technical Reports on Nitrocellulose:

⁴⁷See fostnote 1, page 10.

Nitrocellulose (NC)

<u>o</u>	<u>1</u>	2	<u>3</u>	<u>4</u>	2	<u>6</u>	7	<u>8</u>	2
10 390 420 660 730 960 1020 1150 1150 1240 1350 1410 1430 1580 1660 1810 1830 1990 2210	41 101 231 351 851 971 1031 1041 1151 1201 1231 1331 1351 1401 1421 1501 1541 1681 1751 1811 1831 1841 1851 1961 1961 2071 2181 2201	72 332 402 422 542 572 652 652 952 1012 1242 1362 1392 1642 1852 1912 2022 2102	13 33 43 133 253 253 253 653 653 663 773 1023 1023 1443 1653 1813 1813 1973	4 114 174 174 1894 1024 1074 11774 1384 14574 14574 1824 1824 1824 1824	125 475 485 495 555 705 965 1125 1205 1275 1365 1275 1375 1745 1755 1915 1955	86 576 586 796 916 1016 1026 1256 1316 1316 1516 2556 2056	167 327 407 717 787 987 1187 1267 1297 1407 1447 1487 1587 1717 1817 1817 1847 2137	8 198 208 278 388 408 538 758 758 878 808 838 878 1058 1238 1248 1348 1348 1478 1636 1636 1636 1636 1636 1636 1636 163	19 29 69 169 279 499 659 709 737 779 809 909 1119 1329 1349 1439 1449 1609 2119 2189

Mitroglycerin (Liquid)

Composition:	Molecular Weight: (C3H5H3OQ) 227				
С 15.9 H ₂ C — ОМО ₂	Oxygen Belence: CO: % 3.5 CO % 24.5				
N 18.5 h ₂ c ONO ₂	Density: gm/cc 25°C, Liquid 1.59; 20°C, Liquid 1.596				
0 63.4	Mobile Point: *C Labile form 2.2 Stable form .13.2				
C/H Ratio 0.109	Freezing Point: *C				
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 15	Belling Point: *C Decomposes 145				
Somple 14th 20 mg Picatinny Arsenal Apparatus, In. 1 1b wt 1	Refrective Index, no. 1.4732				
Sample Wt, mg	1.4713				
Friction Pandulum Tests	No				
Steel Shoe	Vecuum Stability Test: cc/40 !1rs, at				
Fiber Shoe	90°C cc/gm/6 hrs 1.6				
BMs Bullet Images Tricks Tricks	- 100°C cc/gm/16 hrs 11+				
Riffe Bellet Impest Test: Trials	120°C				
% Explosions 100	135°C				
Partials 0	150°C				
Burned 0	200 Gram Bomb Saud Test:				
Unaffected 0	Sond, gm Liquid method 51.5				
Explosion Temperature: *C Seconds, 0.1 (no cop used) 1 5 Explodes 222 10 15	Specitivity to initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl				
20	Bellistis Morter, % THT: (a) 140				
	Tousial Teat, % Thif: (b) 181				
75°: International fleet Test: 9: Loss in 48 Hrs	Plate Dank Test: Method				
	Condition				
100° C Heat Test:	Confined				
160° □ Heut Test: 96 Loss, 1st 48 H/c 3. €	Continso				
	Density, gm/cc				
% Loss, 1st 48 H/c 3. €					
96 Loss, 1st 48 H/c 3.€ 96 Loss, 2nd 48 Hrs 3.5 Exp osion in 160 Hrs None	Density, gm/cc Brisance, 16 TNT Detantiles Rate: Confinement Glass Steel				
96 Loss, 1st 48 H/c 3. € 96 Loss, 2nd 48 Hrs 3. 5	Density, gm/cc Brisance, 16 TNT Detanstien Rate:				

Nitroglycerin (Liquid)

Beester Scrattivity Test: Condition		Decemposition Equation: Oxygen, atoms/sec	1017-3	1019.2
Tetryl, gm		(Z/sec)		
Wax, in. for 50% Detonation		Heat, kilocalorie/mole (ΔΗ, kcal/mol)	41.4	45.0
Wax, gm		Temperature Ronge, °C	90-135	125-150
Density, gm/cc		Phase	Liquid	Liquid
Neet of:		Armer Plate Impact Test:		
Combustion, cal/gm	1616	Arms Field Impect Text.		
Explosion, cal/gm	1600	io mm Morter Projectile:		
Gas Volume, cc/gm	715	50% Inert, Velocity, ft.	/sec	
Formation, cal/gm 🎽	400	Aluminum Fineness		
Fusion, col/gm Detonation, cal/gm	1486	500-lb General Purpose Se	embe:	
Specific Heat; co!/gm/*C				
Liquid	0.356	Plate Thickness, inches		
-		1		
Solid	0.315	11/4		
•		11/4		
		13/		
Burning Rate:		1 174		
cm/sec		Comb Drop Test:		
Thermel Conductivity: cal/sec/cm/°C		17, 2000-16 Semi-Armor-l	Piercing Bemb	vs Concrete:
Coefficient of Expension:		Max Safe Drop, ft		
Linear, %/°C		500-15 General Purpose 8	lemb vs Cencs	ate:
Volume, %/°C		Height, ft		
A4- A NA-4		Trials		
Herdness, Mehs' Scele:		Unaffected		
Yanada Madahar		Low Order		
Young's Medulus:		High Order		
E', dynes/cm²				
E, lb/inch ² Density, gm/cc		1001)-Ib General Purpose (Bomb vs Conci	ele:
		Height, ft		
Compressive Strength: Ib/inch²		Trials		
		Unoffected		
Vapor Prossure:		Low Order		
°C mm Mercury °C	mm Mercury	High Order		
20 0.00025 60 30 0.00083 70	0.0188 0.043			
40 0.0024 80	0.043			
50 0.0073 90	0.23	1		

Nitroglycerin (Liquid)

AMCP 706-177

Fragmentation Tref:	Shaped Charge Effectiveness, TNT = 100:
90 mm HE, M71 Projectile, Let WC-91: Denziny, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth
Total No. of Fragments: For TNT	Coloriess Coloriess
For Subject HE , 3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: Propellant ingredient, demolition explosive ingredient, grenade burster ingredient
Total No. of Fragments: For TNT For Subject HE	Method of Looding:
Fregment Velocity: ft/sec	Leading Density: gm/cc
At 9 ft At 251/ ₆ ft Density, gm/cc	Sterege: Method With acetone or other desensitizer.
Blast (Relative to TNT):	generally not stored Hazard Class (Quantity-Distance) Class 9
Air: Peak Pressure Impulse Energy	Compatibility Group Excidation
Air, Confined:	Heat of Transition, cal/gm: Transition:
Under Weter: Peak Pressure Impulse	Liquid → labile 5.2 Labile → stable 28.0 Liquid → stable 33.2
Energy	Hydrolysis, \$ Acid: 1.0 days at 22°C < 0.002
Underground: Peak Pressure Impulse	5 days at 60°C 0.005
Energy	Minutes 10+
	<u> </u>

Mitroglycerin (Liquid)

Gas Evolved at Atmospheric Pressure, cc:

Sample Wt, gm		1.6
Temperature, oc	65	75
Time, hours	20	40
Volume of gas, cc	nil	nil

Viscosity: (c)

°C	Centipoises
10	69.2
20	3€∙0
30 30	21.0
	13.6
50 60	9.4
60	6.8

Pregmentation Test:

20 mm HE, Mark 1, Projectile, Total No. of Fragments for:

Mitroglycerin 22 Tetranitromethane 17

Minimum Propagating Plameter: (d)

Macthylphthalate	Min. Propagating Diameter, inches	Milure in inches
0 5 10 15 20 22.5 25	(3/16 Cmirns) 1/3 1/4 3/4 1 1.55	1/8 1/8 3/16 2/8 7/7

Sensitivity to Electrostatic Machange, scales (test condition, unconfined; no value given for confinement); > 12.5

Solubility, grame of nitroglycerin/100 gm (\$) of:

	ter	Al	cohol .	Trichler	rethylene	Carbon Teta	achloride
<u>°c</u>	Ź	<u>°с</u>	2	°C	4	°c	2
15 20 50	0.16 0.18 0.25	50 0	37•5 54•0	Roma	22	Rm	2

Nitroglyceri : (Liquid)

Carbon Dis	ulfide	gm/100 gm (d), at	25°C in
°c	£	Ether	00
Ambient	1	2:1,Ether:Alcohol	> 100

Soluble in all Proportions in:

Methanol	Phenol
Acetone	Pyridine
Ether	Xylene
Ethyl acetate	Nitrobenzene
Amyl acetate	p-Ni trotoluene
Methyl nitrate	Liquid DNT
Ethyl nitrate	Chloroform
Nitroglycol	Ethyl chloride
Tetrani trodigly cerine	Ethyl bromide
Acetic acid	Tetrachloroethylene
Benzene	Dichloroethylene
Toluene	Trimethyleneglycol Dinitrate

Solubility in NG, of:

Alc	ohol	Ī	NT	7	NT	Wa	ter
<u>ိင</u>	ž	°c	ž	<u>°C</u>	½	°c	2
0 20 50	3.4 5.4	20	?5	20	30	25	0.06

Preparation:

Glycerine is usually nitrated at 25°C, or below, by adding it very slowly to a well agitated mixture of nitric and sulfuric acids, e.g., 40/59.5/0.5, nitric acid/sulfuric acid/water, using an acid/glycerine ratio of approximately 6. Agitation of the reaction mixture is accomplished by use of compressed air. A rapid temperature rise, or appearance of red fumes, automatically requires dumping of the charge, immediately, into a drowning vessel filled with water. After all the glycerine has been added to the nitrator, agitation and cooling are continued until the temperature drops to about 15°C, and the charge is then run into a separator where the NG rises to the top, and is run off to the neutralizer. The nitroglycerin is washed first with water, then with sodium carbonate, and finally with water. The resultant NG when washed with water, produces washings which do not color phenolphthalein, and itself is neutral to litmus paper.

Nitroglycerin (Liquid)

Origin

Nitroglycerin was first prepared in 1846 or 1847 by Ascanio Sobrero, an Italian chemist (Nem Acad Torino (2) 10, 195 (1847)). For several years after this discovery, nitroglycerin attracted little interest as an explosive until Alfred Nobel in 1864 patented improvements in its manufacture and method of initiation (British Patent 1813). Nobel gave the name dynamite to mixtures of nitroglycerin and bon-explosive absorbents, such as charcoal, siliceous earth or Kieselguhr (Dritish Patent 1345 (1867)) Later developments led to gelatine dynamices. ammonia dynamites, and so called straight dynamites. The first propellants using nitroglycerin were called Hallistite (Nobel, Eritish Patent 1471 (1888)) and Cordite (Fel and Dewar, British Patents 5614 and 11,664 (1889)).

Destruction by Chemical Decomposition:

Nitroglycemin is decomposed by adding it slowly to 10 times its weight of 18% sodium sulfide (Mags.9Hgo). Meat is liberated by this reaction; but this is not hazardous if stirring is maintained during the addition of nitroglycemin and continued until solution is complete.

References: 48

- (a) A. E. Blatt. Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1044.
 - (b) Ph. Maoum, Z ges Schiess-Sprengstoffw, pp. 181, 239, 267 (27 June 1932).
 - (c) Inndolt Bornstein, Physikalisch-Chemische Tabellen, 5th Ed. (1923).

International Critical Tables.

B. T. Fedoroff et al, A Manual for Explosive Laboratories, Vol V-IV, Lefax Society, Inc., Philadelphia, 1943, 1946.

- (d) H. A. Strecker, Initiation, Propagation and Luminosity Studies of Liquid Explosives, OSRD Report No. 5509, 3 December 1945.
 - (e) Also see the following Picatinny Arsenal Technical Reports on Mitroglycerin:

<u> </u>	<u>1</u>	2	3	4	2	<u>6</u>	7	<u>8</u>	2
620 660 800 1020 1150 1210 1410 1620 1680	511 551 701 891 1031 1041 1151 1221 1611 1651 1731 1781 1851 1931 2021 2181	652 672 792 922 1142 1282 1362 1542 1662 1742 1752 1992	233 343 673 903 1023 1443 1663 1863 1993	454 1024 1074 1084 1454 1524 1624 1674	1155 1235 1955 2015	1206 1456 1496 1556 1616 1786 1816 1896 2056	817 837 1197 1297 1637 1817 1847	768 1348 1398 1738 1918 2098	69 249 579 709 1349 2119

⁴⁸See footnote 1, page 10.

2201

Nitroguanidine

Competition:		Melecular Weight: (CHI,NI,O2)	104
% c 11.5 NH ₂	•	Oxygen Belence: CO ₂ %	-31
н 3.9 ни— с		CO %	-15.4
и 53.8		Density: gm/c Crystal	1.72
n 30.8	!	Malting Paint: 'C	2 32
C/H Ratio 0.038		Freezing Point: *C	
Impact Sansitivity, 2 Kg Wt:	1.0	Boiling Point: *C	
Bureau of Mines Apparatus, cm Sample Wt 20 mg	47	Refrective Index, no	
Picatinny Arsenal Apparatus, in.	26 7	ng.	1
Sample Wt, mg		n ₂₀	
Friction Pendulum Test:	(e)	Vecuum Stubility Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fibe: Shoe	Unaffected	90°C	(a. 37 →
Riffe Bullet Impact Test: 5 Trials	(e)	100°C	6.44
%		120°C	0.44
Explosions 0		150°C	
Partials 0		150 €	·
Burned 0		200 Grem Bomb Scnd Test:	,
Unaffected 100		Sand, gm	36.0
Explosion Temperature: "C Seconds, 0.1 (no cap used)		Sensitivity to Initiation: Minimum Detanating Charge	, gm
<u>.</u>		Mercury Fulminate	
5 Decomposes 275	•	Lead Azide	0.20
10 15		Tetryl	0.10
20		Bellistic Morter, % TNT: (104
		Trauzi Test, % TNT: (b) 101
75°C International Heat Test: % Loss in 48 Hrs	0.04	, , , , , , , , , , , , , , , , , , , ,	c)
	·	Method	Α .
100°C Heat Test:		Condition	Pressed
% Loss, 1st 48 Hrs	0.18	Confined	No
% Loss, 2nd 48 Hrs	C.09	Density, gm/cc	1 .50 95
Explosion in 100 Hrs	None	Brisance, % TNT	
Flormability Index:		- Detenation Rate: (4	e)
Hygroscopicity: % 30°C, 90% RH		— Condition	
пункасорияту: % 30°С, 90% RH	None	Charge Diameter, in.	
Voletility:	None	Density, çm/cc	1.55
· ····································	HOHE	Rate, meters/second	765 0

Nitroguanidine

regmentation Test:	Shaped Charge Effectiveness, TNT = 100	:
90 mm HE, M71 Projectile, Let WC-91:	Glass Cones Steel Cor	105
Density, gm/cc	Hole Volume	
Charge Wt, Ib	Hole Depth	
Yotel No. of Fragments:	Color: (color)	
For TNT	Color1	ess
For Subject HE		
Stock MP AARSAS Section 11 - A MO P.	Principal Uses:	
3 inch HE, M42A1 Projectile, Let KC-5:	Propellant composition ingredi- bursting charge ingredient	ent,
Density, gm/cc	amenated emerge impression	
Charge Wt, Ib]	
Total No. of Fragmests:	Method of Loading:	
For TNT		
For Subject HE		
	Leeding Density: gm/cc	
regment Velocity: ft/sec	At 3000 pmi	0.95
At 9 ft At 251/4 ft	Storage:	
Density, gm/cc		
source and the second	Method	Dry
		-
lest (Relative to TNT):	Hazard Class (Quantity-Distance)	Class 9
Alex	Compatibility Group	Group I
Peak Pressure	1	•
Impulse	Exudation	
Energy		
Ale Coulines	Solubility, gm/100 gm (%), in:	
Alr, Confined: Impulse	°C	0.44
· · •	Water 25	9.0
Under Weter:	1.0 N Potassium	-
Peak Pressure	Hydroxide 25 40% Sulfuric Acid 0	1.2 3.4+
linpulse	25	8.0+
Energy	* gm/100 cc solution	
Underground:	Booster Sensitivity Test:	(a)
Peuk Pressure	Condition Tetryl, gm	Pressed 100
Impulse	Wax, in. for 50% Detonation	0.67
Energy	Density, gm/cc	1.41
	Heat of:	
	Combustion, cal/gm	1995
	Explosion, cal/gm Gas Volume, cc/gm	7 <u>21</u> 1077
	1 USS YULUME, CC/AM	1077

ころう かんこう

Preparation:

(Chemistry of Powder and Explosives, Davis)

Four hum, ed gms of dry guanidine nitrate is added in small portions to 500 cc concentrated sulfuric acid at 10°C, or below. As soon as all crystals have disappeared the milky solution is poured into 3 liters of ice-water, and allowed to stand until crystallization is complete. The product is filtered, rinsed with water, and recrystallized from about 4 liters of boiling water, yield about 90%.

Origin:

Mitroguanidine was first prepared in 1877 by Jousselin, but it was 1900 before it found use in propellant compositions. During World War I, nitroguanidine was used by the Germans as an ingredient of bursting charge explosives.

Destruction by Chemical Decomposition:

Mitroguanidine is decomposed by dissolving in 15 times its weight of 45% sulfuric acid at room temperature and warming the solution until gas is evolved. Hesting is continued for one-half hour.

References: 49

- (a) L. C. Smith and E. G. Ryster, Physical Testing of Explosives, Pa.t III Miscellaneous Sensitivity Tests; Performance Tests, OSRU Report No. 5746, 27 December 1945.
 - (b) Canadian Report, CE-12, 1 May-15 August 1941.
 - (c) D. P. MacDougall, Mathods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of ROX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) Pepartments of the Army and the Air Force TM 9-1910/TO 11A-1-34, Military Explosives, April 1955.

⁴⁹See footnote 1, page 10.

Mitroguenidine

(*) Also see the following Picatinny Arsenal Technical Reports on Mitroguanidine:

2 1 2 3 6 7 8 9
1490 1391 1282 1183 1336 907 758 1439
2181 1392 1423 2177 1749

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Nitroisobutylelycerol Trinitrate (NIBTN) Liquid

Compositions	Melecular Weight: (ChRCNhO12)	286
% c 16.8 o _g No-cH ₂	Oxygen Palence: CO ₂ % CO %	0.0
$\frac{19.6}{19.6}$ $\frac{0_2 \text{NO} - \text{CH}_2}{19.6}$ $\frac{19.6}{19.6}$	Density: gm/cc 20°C	1.64
0 61.5 02NO-CH2	Melting Point: *C	
C/H Ratio 0.126	Freezing Point: 'C	-39
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, crn 25	Boiling Point: *C	
Sureau of Mines Apparatus, crn 25 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Refrective Index, np. np. np. np. np.	1.4896 1.4874
Friction Pundulum Test: Steel Shoe Fiber Shoe	Vecuum Stability Test: cc/40 Hrs, at 90°C	
Riffe Bullet Impact Test: Trials ** Explosions Partials	120°C 135°C 150°C	
Burned Unaffected	200 Green Bornh Send Test: Sond, gm 0,2 gm sample absorb	ed 26
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 185 10 15	Secultivity to initiation: Minimum Detonating Charge, gm Marcury Fulminate Lead Azide Tetryi	
20	Ballistic Marter, 16 THT:	
	Treated Test, % THT:	
75°C International Heat Test: 96 Loss in 48 Hrs	Place Dent Test: Method Condition	
100°C Mont Test: % Loss, 1st 48 Hrs	Condition Confined	
% Loss, 2nd 48 Hrs	Density, gm/cc	
Explosion in 100 Hrs	Brisonce, % TNT	
Flammability Index:	Y .	nds (1 mm WEJ!
	Condition	Li q uid 0.39
Hygrescopicity: %	Charge Diameter, in. Density, gm/cc	1.64

Mitroisobutylglycerol Trinitrate (MIRTM) Liquid

Fragmentation Test:	Shaped Charge Effectivence, THT = 100:
98 sem HE, M71 Projectile, Let WC-91: Geneity, gm/cc Charge Wt, Ib Tatul No. of Fragments: For TN7 For Subject HE	Glass Cones Steel Cones Hole Volume Hole Depth
	Color: Yellow oil Principal Uses: Gelatinizing agent for
3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib	ni trocellulose
Total No. of Fragments: For TNT For Subject HE	Method of Loading:
Renoment Value to te tear	Leading Density: gm/cc
Fregment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Liquid
Blast (Relative to TPCT):	Hazard Class (Quantity-Distance)
Air: Peok Pressure Impulse Energy	Compatibility Group Exudation
Air, Confined: Impulse Under Weter:	Solubility: Soluble in metayl and ethyl alconols, acetone, ether, ethylenedichloride, chloroform and benzene.
Peak Pressure Impulse Energy	Insoluble in mater carpon Aigulphide, and petroleum ether. Toxicity:
Underground: Prock Pressure Impulse Energy	Slight, decidedly less 200 nitroglycerin. Gelatini ing Action: Slight on nitrocellulose. 82.2°C KI Test; Mir.tes 2

Nitroisobutylglycerol Trinitrate (NIBTN) Liquid

Preparation:

A total of 675 gm 37% formalin is added to 150 gm nitromethane containing 2 gm potassium carbonate hami-hydrate. The first 200 gm formalin is added slowly, keeping the temperature below 30°C, and then the heat of reaction is allowed to raise the temperature to 60°C, and the mixture then heated two hours at 90°C. The reaction mixture is then concentrated at reduced year we and diluted, and this process repeated several times to remove formaldehyde. After the linal concentration the cooled mixture is filtered and the crystalline product recrystallised from alcohol and then several times from ether and dried.

The nitrated product is then obtained by nitrating 50 gm nitroisobutylglycerol with 300 gm mixed acid (60/36/2, sulfuric acid/nitric acid/water) below 15°C for 1.5 hours.

Origin:

This explosive (also called Trimethylolnitromethane Trinitrate, Mitroisobutanetriol Trinitrate, Mitroisobutylglycerin Trinitrate and incorrectly but widely used Mitroisobutylglycerol Trinitrate) was first described in 1912 by Hofwimmer (Z ges Schiess - Sprengstoffw 7, 43 (1912). Hofwimmer prepared the compound by the condensation of 3 moles of formaldehyde with 1 mole of nitromethane in the presence of potassium bicarbonate, the subsequent nitration of the product. The explosive can now be produced from coke, air, and natural gas.

References: 50

- (a) H. A. Amronson, Study of Emplosive's Derived from Nitroperaffins, PATR No. 1125, 24 October 1941.
 - (b) M. Aubry, Men poudr, 25, 197-204 (1932-33); CA 27, 4083 (1933).
 - (c) A. Stettbacher, Witrocellulose 5, 159-62, 181-4, 203-6 (1934); CA 29, 1250 (1935).
 - (d) W. de C. Crater, U.S. Patent 2,112,749 (March 1938); CA 32, 3964 (1938).
- (e) H. J. Hibshman, E. H. Pierson, and H. B. Haas, Ind Eng Chem 32, 427-9 (1940); (A 34, 3235 (1940).
 - (f) A. Stettbacher, Z ges Schiess Sprengstoffv 37, 62-4 (1942); (A 38, 255 (1944).

⁵⁰See footnote 1, page 10.

Composition:		Molecular Weight:	32 5	
% Nitrosterch (12.50% N)	49	Oxygen Solonce:		•
Barium Nitrate	40	CO ₂ %	-19	
Mononi tronsph thalene	7	CO %	8	
Paranitroaniline	3	Density: gm/cc		
011	1	Melting Point: *C		
C/H Ratio		Freezing Point: 'C		
Impact Southfulty, 2 Kg Wt:		Boiling Point: 'C		
Bureau of Mines Apparatus, cm Sample Wt 20 mg	.51	Refrective Index, no		
Picatinny Arsenal Apparatus, in.	8	_		
Sample Wt, mg		n _B		
		n ₂		
Friction Pendulum Test:		Vacuum Stebility Test:		
Steel Shoe Crackle	es, snaps	cc/40 Hrs, at		
Fiber Shoe Unaffe	e te d	50°C		
Rifle Bellet Impact Test: 10 Triols	8 Triels*	100°C	11+	
•		120°C		
Explosions 97	% 0	135°C		
Partials 0	13	150°C		
Burned 0	0	200 Gram Bomb Send Test:		
Unoffected 10 *Packed in paper	87	Sand, gm	3 9•5	
Explosion Terreporuture: °C		Sensitivity to Initiation:		-
Seconds, 0.1 (no cop used)		Minimum Detonating Charge, gm		
1		Mercury Fulminate	0.26	
5 Decomposes 195		Lead Azide		
16		Tetryl		
15 20		Ballistic Morter, % TNT: (a)	96	•
		Trouzi Test, % TNT:		_
75°C International Heat Test: % Loss in 48 Hrs	0.2	Method		
100°C Heet Test:		Condition		
% Loss, 1st 48 Hrs	0.3	Confined		
% Loss, 2nd 48 Hrs	0.3	Density, gm/cc		
Explosion in 100 Hrs	None	Brisance, % TNT		
Flemmebility Index:	·	Detenation Rate: Confinement		
		Condition		
Hygrescopicity: % 30°C, 90% RH	2.1	Charge Diameter, in		-
		Density, gm/cc		
Volatility:				

Nitrostarch Demolition Explosive (NSX)

Fragmentation Test:	Shoped Charge Effectiveness, Th	rr = 100:
90 mm HE, M71 Projectile, Let WC-91:	Gloss Cones	Steel Cones
Density, gm/cc	Hole Volume	
Charge Wt, Ib	Hole Depth	
Total No. of Fragments:	Color:	
For TNT		
For Subject HE	Principal Uses: Demolition,	bursting charges,
3 iach HE, M42A1 Projectile, Let KC-5:	and priming	
Density, gm/cc	1	
Charge Wt, Ib		
Charge Wi, ib		
Total No. of Fragmonts:	Method of Looding:	Hand tamped
For TNT		
For Subject HE		
	Leading Density: gm/cc	
Fregment Velocity: ft/sec	Apparent	0.92
At 9 ft At 25½ ft	Sterege:	
Density, gm/cc		
Density, gm/cc	Method	Dry
Blast (Relative to TNT):	Hazard Class (Quantity-Distor	nce) Class 9
Air:	Compatibility Group	Group I
Peak Pressure		
Impulse	Exurtation	None
Energy		
Air, Confined:	120°C Heat Test:	
Impulse	0-1 64-1	Minutes
AA A SAA	Salmon Pink Red Fumes	70 255
Under Weter: Peak Pressure	Explodes	2 56
Impulse	<u>-</u>	
Energy		
Undergreund: Peak Pressure		
impulse		
Energy		
		-

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Nitrostarch Pemolition Explosive (NSX)

Freparation: (b)

The nitration of starch proceeds with the formation of hexanitro starch according to the following equation:

 $2C_6H_{10}O_5 + 6HMO_3 \rightarrow C_{12}H_{11}O_4(OMO_2)_6 + 6H_2O$

Tapioca starch is considered the best for nitration purposes, although other starches give inirly stable products. The starch, pretreated to remove pils, fats and water soluble impurities, is dried and acreened. Feeding of the dried starch into stainless steel nitrators containing mixed acid (62%-63% HNO₂ and 37%-39% H₂SO₃) is done clowly with constant agitation of the mixture. The heat evolved must be controlled by cooling coils. The nitrated starch is separated from the spent acid, washed with a large amount of water and centrifuged. Final drying is on trays heated to 35°-40°C with air. This product is so sensitive even a static discharge might cause explosion.

Hitrostarch demolition explosives contain a high percentage of nitrostarch, an oxidizing agent, mineral oil, a stabilizer and/or other ingredients.

Origin:

Ritrostarch was first prepared in 1833 by Branconnot, who called it xyloidine (Ann chim phys [2] 52, 290 (1833)). T. J. Pelouse studied xyloidine further and reported its explosive properties (Compt rend 7, 713 (1836). It found military use in the United States during World Wars I and II as blasting explosives and as an ingredient of bursting charges and priming compositions.

References: 51

- (a) W. R. Tomlinson, Jr., Physical and Explosive Properties of Military Explosives, PATR No. 1372, 29 November 1943.
- (b) G. D. Clift and B. T. Fedoroff, A Manual for Explosives Laboratories, Vol I, Lefax Society, Inc., Philadelphia (1942).
 - (c) Also see the following Picatinny Arsenal Technical Reports on Mitrostarch Explosives:

1	2	<u>4</u>	I	<u>8</u>	2
1611	782 2032	1034	1117	8 38 848	1 2 69

⁵¹See footnote 1, page 10.

Octol, 70/30

Composition:		Melecular Weight:	265
% HNX	70	Oxygen Belence:	
DIA.	• -	CO, % CO %	-38 -7.5
TMT	30		
		Benefity: gm/cc Chat	1.80
		Molting Point: *C	
C/H Ratio		Freezing Point: "C	
impact Sensitivity, 2 Kg Wt:		Boiling Point: *C	
Bureou of Mines Apparatus, cm Sample Wt 20 mg		Refrective Index, nº	
P catinny Arsenal Apparatus, in.	18	n <u>e</u>	
Sample Wt, mg	26	n _p	
Frietien Pendulum Test:		Vocuum Stability Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Filter Shoe	Unaffected	90°C	
Rifle Sullet Impact Test: Trials		100°C	
%		120°C	0.37
Explosions 70		135°C	
Partials		150°C	
Burned		200 Grem Bomb Sand Test:	_
Unaffected		Sond, gm Emploratory	58.4
Explosion Temperature:	°C	Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
l 5 Flames erratically	335	Mercury Fulminata	
10		Lead Azide	0.30
15		Tetryi	
20		Ballietic Morter, % TNT:	115
SEA Commenter of Maria Park		Treuzi Test, % TNT:	
75 C International Heat Tust: % Loss in 48 Hrs		Plate Dent Test: Method	
		Condition	
100°C Heat Tent:	•	Confined	
% Loss, 1st 48 Hrs		Density, gm/cc	
% Loss, 2nd 48 Hrs Explosion in 100 Hrs		Brisance, % TNT	
		Detenation Rate:	
Flommobility Index:		Confinement	None
		Condition	Cast
Hygrescopicity: %		Charge Diameter, in.	1.0
Volatility:		Density, gm/cc	1.80
		Rate, meters/second	8 37 7

Octol, 70/30

Seaster Sensitivity Test: Condition	,	Decomposition Equation: Oxygen, groms/sec
Tetryi, om	•	(Z/sec)
Wax, in. for 50% Detonation		Heat, kilocalorie/mole
· · · · ·		(ΔH, kcal/mol)
Wax, gm		Temperature Range, °C
Density, gm/cc		Phose
Heat of:	2722	Armer Plate Impect Test:
Combustion, cal/gm	1074	
Explosion, car/gm	•	60 mm Marter Projectile:
Gas Volume, cc/gm	847	50% Inert, Velocity, ft/sec
Formation, cal/gm		Aluminum Fineness
Fusion, cal/gm		500-lb General Purpose Bomhs:
Specific Heet: c * /gm/°C		
appenies susse; C (right) C		Plate Thickness, inches
		1
		162
		11/4
		154
Surning Rate:		
cm/sec		Somb Drop Test:
Thermal Conductivity:		- John Drop Test;
cal/sec/cm/°C		T7, 2000-lb Semi-Armos-Piercing Bomb vs Concrete:
Coefficient of Expension:		Max Safe Drop, ft
Linear, %/°C		500-th General Purpose Bomb vs Concrete:
Volume, %/*C		Height, ft
		Trials
Hardness, Mahs' Scale:		Unoffected
		Low Order
Young's Modulus:		High Order
E', dynes/cm²		
E, ib/inch²		1000-lb General Purpose Bomb vs Concrete:
Density, gm/cc		
Commence Street A. th. 17-1-17	1510	Height, ft
Compressive Strength: Ib/inch²	See below	Trials
		Unaffected
Vapor Pressure:		Low Order
*C mm Mercury		High Order
Compressive Strength: 1b/inch2	*	
Average (10 tests)	1510	Ultimate Deformation: %
High Low	1740 1330	Average (10 tests) 2.26
 -	- J.J.	High 2.58 Low 1.97

^{*}Test specimen 1/2" x 1/2' cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Octol, 70/30

Fragmentation Test:	Shoped Charge Effectiveness, TNT == 100:	
(#) man HE, M71 Projectilis, Let WC-91; Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Dcpth	
Total No. of Fragments: For TNT	Color:	Buff
For Subject HE 3 lack ME, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: HE projectile and bomb	filler
Total No. of Fragmonds: For TNT For Subject HE	Method of Loading:	Cast
Fregment Velocity: 11/sec At 9 ft At 2514 ft	Looding Density: gm/cc Storage:	1.80
Density, gm/cc	Method	Dry
Blant (Relative to TNT):	Hazarri Class (Quantity-Distance)	class 9
Air: Peak Pressure Impulse Energy	Compatibility Group Exudation	Group I
Air, Confined: Imputse Under Weter: Peak Pressure Imputse Energy	Work to Produce Rupture: ft-lb/inch ³ Average (10 tests) High Low Efflux Viscosity, Saybolt Seconds:	* 1.55 1.87 1.10 5 9
Underground: Peak Pressure Impulse Energy	*Test specimen 1/2" x 1/2" cylinder (s mately 3 gm) pressed at 3 tons (6,000 total load or 30,000 psi with a 2 min time of dwell.) 1b)

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Octol, 70/30

Effect of Altitude. Charge Diameter and Degree of Confinement on Detonation Velocity* (Reference b)

,			h Column		h Column
Explcaive	Simulated Altitude,	Confined	Unconfined	Confined	Unconfined
	Feet	m/s	m/8	m/s	E/8
70/30, RDX/TNT;	Ground	7900	8100	7660	8030
density, gm/cc 1.62	30,000	8020	8120	7900(4)	7800
	60,000	8040	8140	8010	7950
	90,000	8060	7980	8010	7710
Average		8005	8085	7895	7873
70/30, HMX/TNT;	Ground	7960	7900(4)	7870	7640(4)
density, gm/cc 1.61	30,000	8050	8060	7930	7710
	60,000	8020	7 9 30	7890	7650
	90,000	7950	8000	7940	7650
Average	:	7995	7973	7908	7663

^{*70/30} Octol confined charge in 1/4" steel tube, AISI 1015 seamless, 1" diameter 18" long, and 2" diameter 7" long. All means were determined from sets of five values unless otherwise indicated by (). A 26 gm tetry booster was used to initiate each charge.

Average Pragment Velocities at Various Altitudes* (g)

		Simulated Altitude, Feet			et
Explosive	Charge Diameter,	Ground	30,000	60,000	90,000
	Inches	m/s		B √8	
70/30, RDX/TNT	1	3415	3672	3666	3685
	2	4647	5192	523€	6011
70/30, HMX/TMT	1	3366	3680	4014	3617
	2	4703	5464	6089	6111

^{*}Outside diameter 2.54"; inside diameter 2.04"; length 7".

CONTRACTOR OF THE SECOND

Octol, 70/30

Tensile Strength:*

	lb/inch2
Average (8 tests)	169
High	204
Low	128

*Test specimen as per Picatinny Arsenal sketch XL-076B, at 21°C.

Modulus of Elasticity:*

	lb/inch ²
Average (10 tests)	1b/inch ² 73,200
High	79,300
Low	63,oc

*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 ps; with a 2 minute time of dwell.

Setback Sensitivity Test: ()

Critical Pressure	92,000 psi*
Density, pm/cc	1.72

*Pressure below which no initiation is obtained and above which an increasing percentage of initiations can be expected as the setback pressure increases.

Pit Fragmentation Test:

105 mm MR HE Projectile:

Weight Group, grains	No. of Fragments
1/2 - 2	1297
2 - 5	665
5 - 10	1.97
10 - 25	661
25 - 50	471
50 - 75	247
75 - 150	322
150 - 750	295
750 - 2500	12
Total Number	4+67

Composition; 96		Melecular Weight:	276
70 180X	75	Oxygen Belence:	
,	17	CO ₂ %	- 235 -€.3
TNT	25	CO %	-5 · 3
		Density: gm/cc Caz 1	1.81
		Malting Point: °C	
C/H Ratio		Freezing Point: "C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm		Beiling Point: *C	
Sample Wt 20 mg		Refrective Index, no	
Picatinny Arsenal Apparatus, in. Sample Wi, mg	17 25	n _m	
Sumple Wi, mg		n ₃₀	
Fristian Pandulum Test:		Vecuum Stability Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unsifected	90.C	
2iffe Sullet Impact Test: 10Trials 5	·	— 100•C	
3/16" Steel	1/8" Al	150.C	0.39
Explosions 70	70	135°C	
Portiols		150°C	
Burned		200 Grem Bomb Send Test:	
Unaffected 30	30	Sond, om Exploratory	62.1
Explosion Temperature:		Scalitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm Mercury Fulminate	
5 Flames erratically	7 350		
10	3,70	Lead Azide	0.30
13		Tetryl	
20		Bellistic Morter, % TNT:	116
		Trouxi Teet, % TNT:	
75°C International Heat Test: 96 Loss in 48 Hrs		Plate Dent Test: Method	
160°C Heat Test:		Condition	
% Loss, 1st 48 Hrs		Confined	
% Loss, 1st 46 Hrs		Density, gm/cc	
Explosion in 100 Hrs		Brisance, % TNT	
		- Detenation Rate:	
Flommobility Index:		Confinement	None
		- Condition	Cast
Hygrasospicity: %		Charge Diameter, in.	1.0
		Density, gm/cc	1.81
Volatility:		Rate, meters/second	8643

		T	
Booster Sensitivity Test: Condition		Decemposition Equation:	
_		Oxygen, atoms/sec (Z/sec)	
Tetryl, gm		Heat, kilocalorie/mole	
Wax, in. for 50% Detonation		(ΔH, kcal/mol)	
Wax, gm		Temperature Range, *C	
Density, gm/cc		Phase	
Heat of:		Armor Plate Impact Test:	
Combustion, cal/gm	267 6	Armor France (impact) text:	
Explosion, cal/gm	1131	60 mm Morter Projectile:	
Gas Valume, cc/gm	830	50% Inert, Velocity, ft/sec	
Formation, cal/gm		Aluminum Fineness	
Fusion, cal/gm	29.4*		
*Calculated for 76.9% HMX, 23.1		500-lb General Purpose Samba:	
Specific Heat: cal/gm/°C -79°C	**	Olata Thistones inches	
-80° to +80°C	0.200	Plate Thickness, inches	
-80° to +80°c 33° to 74°c	0.245		
90° to 150°C	0.323	1	
**Determined for 76.9% HMX, 23.	1% TNT.	11/4	
		11/2	
		1%	
Burning Rate:			
cm/sec		Somb Drop Test:	
Thermal Conductivity:]	
ca:/sec/cm/°C		77, 2000-lb Sami-Armer-Piercing 9	emb vs Concrete:
B-All-t-A-A-B		Max Safe Drop, ft	
Coefficient of Expension: Linear, %/°C			
E11801, 30, C		500-lb General Purpose Bamb vs C	ionerota:
Volume, %/°C		Height, ft	
		Trials	
Hardness, Mahs' Scale:		Unoffected	
		Low Order	
Young's Modulus:		High Order	
E', dynes/cm²			
E, lb/inch ²		1000-th General Purpose Bomb vs C	encrate:
Density, gm/cc			
Company Strength: It (Inch!)	1340	Height, ft	
Compressive Strength: Ib/inch ²	See below	Trials	
		Unaffected	
Vapor Pressure:		Low Order	
°C mm Mercury		High Order	
Compressive Strength: 1b/inch2	***		
	1340	Ultimate Deformation: %	
Average (10 tests)	1340		
Average (10 tests) High Low	1560 1040	Average (10 tests)	2.43 2.69

***Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

ragmentation Test:	Shaped Charge Effectiveness, TNT = 109:				
90 mm HE, M71 Projectile, Let WC-91:	Glass Canes Steel Cane	15			
Density, gm/cc	Hole Volume				
Chorge Wt, Ib	Hole Deptin				
Total No. of Fragments:	Color:	Buff			
For TNT		2-2-2			
For Subject HE	Frincipal Uses: HE projectile and bomb filler				
3 inch HE, M42A1 Projectile, Let KC-5:					
Density, gm/cc					
Charge Wt, Ib	•				
Total No. of Fragments:	Method of Looding:	Cast			
For TNT					
For Subject HE	Leading Density: gm/cc	1.81			
agment Valualty: ft/sec		1.01			
At 9 ft	2				
At 251/2 ft	Sterage:				
Density, gm/cc	Method	Dry			
est (Relative to TNT):	Hazard Class (Quantity-Distance)	Class 9			
Ale:	Compatibility Group	Group I			
Peak Pressure					
Impulse	Exudation				
Energy					
Alr. Confined:	Work to Produce Rupture: ft-lb/in	ch ³ *			
Impulse	Average (10 tests)	1.31			
	High	1.57			
Under Water: Peak Pressure	Low	1.07			
Impulse	Efflux Viscosity, Saybolt Seconds	: 9.0			
Energy					
Underground:	1				
Peak Pressure	l				
Impulse	}				
Energy					
	*Test specimen 1/2" x 1/2" cylinde mately 3 gm) pressed at 3 tons (6 total load or 30,000 psi with a 2 time of dwell.	,000 lb)			

Frequent Velocity Test: M26 Hand Grenade:

(e)

Explosive	Average Fragment Velocity, ft/sec over lat 5 feet					
Composition B	515#					
75/25 Cycletol	4008					
75/25 Octol	#0#8					

	lb/inch ²
Average (10 tests) High	266 330
LOW	226

*Test specimen as per Picatinuy Arsenal sketch XL-076B, at 21°C.

Modulus of Elasticity:*

	lb/inch2
Average (10 tests)	62,100
High	75,900
LOW	45,200 i

*Test specimen $1/2^n \times 1/2^n$ cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total l(3d or 30,000 psi with a 2 minute time of dwell.

Setback Sensitivity Tele: (a)

Critical Pressure 176,000 pai*
Tomaity, ga/cc 1.80

*Frescrive below which no initiation 10 obtained and above which an increasing percentage of initiations can be expected as the setback pressure increases.

Pit Fragmentation Test:

(a)

105 mm M1 HE Projectile:

Weight Group, grains	No. of Fragments
1/2 - 2	1611
2 - 5	777
5 - 10	535
10 - 25	719
25 - 50	480
50 - 75	246
75 - 150	339
150 - 750	293
75C - 2500	. 8
Total Number	5008

Octol, 70/30; Octol, 75/25

Preparation:

Water-wet HRK is added slowly to molten TNT in a steam-jacketed kettle at a temperature of 100°C. The mixture is heated and stirred until all moisture is evaporated. The composition is cooled to a satisfactory pouring temperature and cast directly into ammunition components or prepared in the form of chips to be stored for later use.

References: 52

- (a) 1st Indorsement from Chief, Explosives Development Section, to Chief, Explosives Research Section, Picatinny Arsenal, dated 12 May 1958. Subject: "Properties of Octols and HTA-3."
- (b) A. W. O'Brien, Jr., C. W. Plummer, R. P. Woodburn and V. Philipchuk, <u>Detonation Velocity Determinations and Fragment Velocity Determinations of Veried Explosive Systems and Conditions</u>, <u>Mational Northern Corporation Final Summary Report NNC-F-13</u>, February 1958 (Contract DAI-19-020-501-ORD-(P)-58).

⁵²See footnote 1, page 10.

PB-RDX

Sempositica:		Molecular Weight:	245
RDX	90	Oxygen Selence:	
	_	CO. %	-62
Polystyrene (unmodified)	8.5	CO %	-18
Dioctylphthalate	1.5	Despity: gm/cc Unpressed Pellet pressed at 30,000 psi Melling Point: *C	0.81
C/H Ratio		Freezing Point: *C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	Unpressed 28	Boiling Point: "C	
Somple Wt 20 mg		Rofrective Index, no	
Picatinny Arsenal Apparatus, in		n _{ss}	
Sample Wt, mg	20	n _s	
Friction Pondulum Test:			
Steel Shoe	Unaffected	Vocuum Stability Test: cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	••••
		- 100°C	
Rifle Bullet Impact Test: 10 Trials	, *	120°C	0.41
Explosions 10		135°C	
Partials 90		150°C	
Burned 0			
Unaffected 0		200 Grem Bemb Send Test: Sond, gm	
Explesion Temperature: *(Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5 Smokes 21	75	Lead Azide	
10		Tetryl	
15			
20		Ballistic Morter, % TNT:	
2210 to a contract to a 22		Treusi Test, % TNT:	
75 °C International Heat Test: % Loss in 48 11rs		Plate Sent Test: Method	
100°C Heat Test:		Condition	• .
% Loss, 1st 48 Hrs	0.00	Confined	
% Loss, 2nd 48 Hrs	0.00	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
Flow-nobility Indon		Detenation Rate:	
Flammability Index:		Confine nent	
Hygroscopicity: %		Condition	
		Charge Diameter, in.	
* Test procedure described	in PATR No. 2247,	Density, gm/cc	
May 1956.		Rate, meters/second	

Beaster Sensitivity Test: Condition	Decomposition Equation: Oxygen, atoms/sec
Tetryl, gm	(Z/sec)
Wax, in. for 50% Detonation	Heat, kilocolorie/mole
Wax, gm	(ΔH, kcal/mol) Temperature Range, °C
Density, gm/cc	Phase
Heat of: Combustion, col/gm 302	Armor Plate Impact Test:
Explosion, cal/gm 98	•
Gas Volume, cc/gm	60 mm Mortar Projectile:
Formation, cal/gm	50% Inert, Velocity, ft/sec
Fusion, cal/gm	Aluminum Fineness
	500-lb Ganerai Purposo Bombs:
Specific Heet: cal/gm/°C	Dieta Thickness to the
	Plate Thickness, inches
	1
	11/4
	11/2
	154
Barning Rate:	
cm/sec	Bomb Drop Text:
Thermal Conductivity:	
col/sec/cm/°C	17, 2000-16 Semi-Armor-Piercing Bomb vs Concrete:
Confficient of Expension:	Max Safe Drop, ft
Linear, %/°C	ROO C. Command Dayman Day 1
,	500-i3 General Purpose Remb vs Concrete:
Volume, %/°C	Height, fr
Mandage Adabat Santa	Trials
Hardness, Mahs' Scale:	Unaffected
Young's Modulus: See below	Low Order
E', dynes, cm²	High Order
E, lb/inch ²	
Density, gm/cc	1000-lb General Purpose Bomb vs Concrete:
	Height, ft
Compressive Strongth: Ib/inch ² 2403 211	+9 Trials
Percent 8.9 13.	-1 Unaffected
Vapor Pressure:	Low Order
*C mm Mercury	High Order
Young's Modulus: * (a) Temperatur	1
Ambient 95	<u> </u>
	831
Density, gm/cc 1.60 1.	.57

^{*}Pellets (Lot OAC-596-55) 0.750 inch diameter by 0.750 inch long, pressed at 30,000 ps: with 30-second dwell.

Acthod of Load acting Density 0 10 10 10-19 Acroge: Method Hazard Class Compatibility	High wechanics explosive ling: 20 30 1.59 1.62	Pressed , psi x 10 ³ Dry Class 9		
Hole Depth Color: Inincipal Uses: Author of Load aciding Density 0 10 10 10 10 Horage: Method Hazard Class Compatibility	High Eachanica explosive ling: 20 30 1.59 1.62	Pressed , psi x 10 ³ Dry Class 9		
Author of Load acting Density 0 10 -10 1.49 terage: Method Hazard Class Compatibility	emplosive ling: r: gm/cc Pressed 20 30 1.59 1.62	Pressed , psi x 10 ³ Dry Class 9		
Acthod of Load aciding Density 0 10 1.49 Norage: Method Hazard Class Compatibility	emplosive ling: r: gm/cc Pressed 20 30 1.59 1.62	Pressed , psi x 10 ³ Dry Class 9		
Acthod of Load aciding Density 0 10 1.49 Norage: Method Hazard Class Compatibility	emplosive ling: r: gm/cc Pressed 20 30 1.59 1.62	Pressed , psi x 10 ³ Dry Class 9		
Acthod of Load acting Density 0 10 10 10-19 Acroge: Method Hazard Class Compatibility	emplosive ling: r: gm/cc Pressed 20 30 1.59 1.62	Pressed , psi x 10 ³ Dry Class 9		
Acthod of Load acting Density 0 10 10 10-19 Acroge: Method Hazard Class Compatibility	emplosive ling: r: gm/cc Pressed 20 30 1.59 1.62	Pressed , psi x 10 ³ Dry Class 9		
needing Dentity 0 10 10 10 1,49 Norage: Method Hazard Class Compatibility	e: gm/cc Pressed 20 30 1.59 1.62	l, psi x 10 ³ Pry Class 9		
needing Dentity 0 10 10 10 1,49 Norage: Method Hazard Class Compatibility	e: gm/cc Pressed 20 30 1.59 1.62	l, psi x 10 ³ Pry Class 9		
needing Dentity 0 10 10 10 1,49 Norage: Method Hazard Class Compatibility	e: gm/cc Pressed 20 30 1.59 1.62	l, psi x 10 ³ Pry Class 9		
needing Dentity 0 10 10 10 1,49 Norage: Method Hazard Class Compatibility	e: gm/cc Pressed 20 30 1.59 1.62	l, psi x 10 ³ Pry Class 9		
needing Dentity 0 10 10 10 1,49 Norage: Method Hazard Class Compatibility	e: gm/cc Pressed 20 30 1.59 1.62	l, psi x 10 ³ Pry Class 9		
0 10 10 1,49 Norege: Method Hazard Class Compatibility	20 30 1.59 1.62 (Quantity-Distance)	Dry Class 9		
0 10 10 1,49 Norege: Method Hazard Class Compatibility	20 30 1.59 1.62 (Quantity-Distance)	Dry Class 9		
10 1.49 Norege: Method Hazard Class Compatibility	1.59 1.62 (Quantity-Distance)	Dary Class 9		
Method Hazard Class Compatibility	(Quantity-Distance)	Dary Class 9		
Method Hazard Class Compatibility) Class 9		
Hazard Class Compatibility) Class 9		
Hazard Class Compatibility) Class 9		
Compatibility		Class 9		
•	Group	Group I		
•				
_				
Exudation None				
Rockwell Hardness, "R" Scale: (a)				
1/2 inch diameter Penetrator, 60 Kg Load:				
Pellet	Specific			
Nc.*	Gravity	Ha-dness		
1	1.624	84		
2	1.623	90		
3	1.611	84		
4 5		80 75		
6		73		
7	1.548	62		
B	1.524	49		
Pellets (Lot in diameter	HOL-F-93) were and 3/4 inch hig	1-1/2 inches		
	1/2 inch dis Pellet No.* 1 2 3 4 5 6 7 8	1/2 inch diameter Penetrato Pellet Specific No.* Gravity 1 1.624 2 1.623 3 1.611 4 1.600 5 1.590 6 1.571 7 1.548		

Sensitivity of PB-RDX and 98/2 RDX/Stearic Acid fer ets* to Initiation by Type II Special Blasting Caps

De11-4-	Gap	(Distance	e From	Bese of (Cap to Po	ellet), 1	nches
Pellets	0.250	0.300	0.350	0.400	0.450	0.500	0.7
PB-RDX with Pellet Density 1.55 gm/cc	_						
Ho. of Trials		8	5	6	2	1	1
Average Depuh of Plate Indentation, inches **	0.082	J.090	0.087	0.080	0.080	_	_
No. of Failures	0	1	3	4	1	1	1
PB-RDX with Pellet De.sity 1.60 gm/cc							
No. of Trials	_ 3	8	9	4	3	5	2
Average Depth of Plate Indentation, inches **	0.090	0.089	0.087	0. 000	0.087	0.075	
No. of Failures	0	0	2	3	2	3	
98/2 FDX/Stearic Acid With Pellet Density 1.63 gm/cc							
No. of Trials	5	3	5	,	5	5	5
Average Depth of Plate Indentation, inches **	0.109	0.096	0.095	0.092	0.097	0.087	
No. of Failures	0	1	0	3	4	4	5

Performance of PB-RDX as Booster: (b, d)

Ten 2.75 inch HEAT MI Rocket Heads were unaffected in performance by storage at 71°C for 28 days. Thus, PB-RDX was not desensitized by contact with TNT-bearing explosives. Tetryl, similarly used, becomes desensitized when stored in bursting charges at elevated temperatures.

In addition, 108 modified M307Al 57 mm projectiles were fired for performance against armor. Each round contained a PB-RDX booster pellet. There was no evidence in these firings that the projectiles were inadequately boostered.

Mild steel plate $5" \times 5" \times 1"$.

Preparation:

The purchase description sheet for polystyrene-bonded RDX (X-PA-PD-1088, 25 October 1956) requires that the PB-RDX shall be a mixture of RDX, coated and surrounded by a homogeneous mixture of polystyrene and dioctylpathalate. The specified percentage of RDX shall consist of a mixture of 75% Type B, Class A RDX and 25% Type B, Class E RDX. The granulation of the unpressed composition shall be as follows:

T	rough U. S. Standard Sieve No.	Minimum %	Maximum %
	6	100	
	12	100 60	
	20		2
	35		ō

Two methods have been reported for the preparation of PB-RDX (Reference: Los Alamos Scientific Laboratory, Contract W-7405-Eng 36 with U.S. Atomic Energy Commission, Report No. IA-1448). The earlier method employed a Baker-Perkins type mixer to blend the components. This procedure gave a product with good pressing characteristics. However, the molding composition was nonuniform in granulation and tended to be dusty. The slurry method of PB-RDX preparation gave a product which was uniform, free-flowing and dustless. In addition, PB-RDX granulated by the slurry method exhibited satisfactory drying, handing and pressing characteristics.

The final procedure incorporating the better features found from the study of such variables as solvents, solvent/plastic ratios, lacquer addition and temperature, agitation, RDX particle size distribution, dispersants and rosin additive, was as follows (Reference c):

Forty-two and five-tenths grams (42.5 gm) of polystyrene and 8 cc dioctylphthelate were dissolved in 200 cc toluene in a lacquer dissolver. Steam was introduced into the jacket until the temperature reached 65°C. The lacquer was agitated constantly until it was ready to be added to the granulator. This lacquer contained a 1:4 ratio of plastic-plasticizer to toluene.

Four hundred and fifty grams (450 gm) of RDX and 4500 grams of H₂O (ratio 1:10) were added to the granulator. The agitator was set for 400 rpm and the temperature was raised to 75° C by introducing steam into the Jacket. The temperature differential between the lacquer solution and the RDX/water slurry was 5° to 10° C.

The lacquer solution was poured through the charging funnel into the granulator. As soon as the lacquer was added, a solution of gelatin in water was added, and the mixture was agitated until the lacquer was well dispersed in the RDX slurry (approximately 5 minutes). Granulation took place at this point. Steam was introduced again into the jacket to distill the solvent until the temperature reached 98°C. Cooling water was then run into the jacket to cool the batch to 40°C. The coated material from the granulator was collected on a Buchner funnel and dried in a tray at 70°C for 24 hours. Temperatures below 70°C did not furnish enough heat, but a temperature of 80°C produced stickiness and caking of PB-RDX.

Origin:

An explosive consisting of RDX coated with polystyrene plasticized with dicetyphthalate was initially developed in 1952 for the Atomic Energy Commission by Los Alamos Scientific Laboratory of the University of California (Contract W-7405-Eng 36 with U. S. Atomic Energy

PB-RDX

Commission, Report No. IA-1448). The specific formulation of 90/8.5/1.5 RDM/polystyrene/dioctylphthclate was subsequently standardised by Los Alamos. This emplosive, originally designated PBK, has been redesignated PB-RDM. The detailed requirements for the present polystyrene-bonded RDM(PB-RDM) are given in purchase description X-PA-PD-1088, 25 October 1956.

References; 53

- (a) B. J. Zlotucha, T. W. Stevens and C. E. Jacobson, <u>Characteristics of Polystyrene-Bonded RDK(PB-RDK)</u>, PATR No. 2497, April 1958.
- (b) A. J. Pascasio, The Suitability of a Bare PRX Booster Pellet in the 2.75 Inch ML HEAT Rocket Head, PATR No. 2271, November 1955.
- (c) J. L. Vermillion and R. C. Dubberly, Plastic-Bonded PNK, Its Preparation by the Slurry Method, Holston Defense Corporation, Control No. 20-7-16 Series A (PAC 1081), 5 March 1953.
- (d) C. J. Eichinger, Report on Cartridge HEAT 57 mm M307Al (Mod) with Modified Copper Liner, Aberdeen Proving Ground, Development and Proof Services, First Report on OC Project TA3-5204, October 1957.

⁵³See footnote 1, page 10.

Pentserythritol Trinitrate (PETRIN)

Composition:	Melecular Weight: (C5H9N3O10)	271			
C 22.1	Oxygen Belence: CO ₂ % CO %	-2 7			
H 3.3 HOCH ₂ — C— CH ₂ ONO ₂ N 15.5	Density: gm/cc	1.54			
O 59-1	Molting Point: *C	26 to 28			
C/H Ratio 0.141	Freezing Point: *C				
Impact Sensitivity, 2 Kg Wr:	Beiling Point: *C 4 mm Hg Decomposes	130			
Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 5 to 10 Sample Wt, mg 38	Refrective Index. no. no. no.				
Friction Fundulum Test: Steel Shoe Fiber Shoe	Vocuum Stability Test: cc/40 Hrs, at 90°C	0.5			
Riffe Bullet Impact Test: Trials % Explosions Partials	100°C 120°C 135°C 150°C	2.54 to 5.69			
Burned Unoffected	200 Grem Bomb Sand Test: Sand, gm				
Explosion Temperature: "C Seconds, 0.1 (no cap used) 1 5 10 15	Sensitivity to initiation: Minimum Detonating Charge, grn Mercury Fulminate Lead Azide Tetryi Ballistic Marker, % TNT:				
20	Trough Toot, % TNT:				
75°C International Heat Test: % Loss in 48 Hrs	Plate Sent Test: Method				
160°C Heet Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Condition Confined Density, gm/cc Brisance, % TNT				
Flemmobility Index:	Detenation Rate: Confinement				
Hygrescapicity: %	Continement Condition Charge Diameter, in.				
Volatility:	Density, gm/cc Rate, meters/second				

Pentaerythritol Trinitrate (PETRIN)

Fregmentation Test:	Shaped Charge Effectiveness, TNT = 100:	
90 mm HE, M71 Projectile, Let WC-91:	Glass Cones Steel Cone	•
Density, gm/cc	Hole Volume	
Charge Wt, Ib	Hole Depth	
Total No. of Fragments:	Color:	17.14.
For TNT	Caller	Whi te
For Subject HE		
	Principal Uses: Explosive, propellant igniter ingredient	i or
3 inch HE, M42A1 Projectile, Let KC-5:	28	
Density, gm/cc		
Charge Wt, Ib		
Total No. of Fragments:	Method of Looding:	
For TNT	monage.	
For Subject HE		
	Leeding Density: gm/cc	
Fragment Velocity: ft/sec		
At 9 ft At 251/4 ft	Storege:	
Density, gm/cc		
	Method	Dry
Sleet (Relative to TNY):	Hazard Class (Quantity-Distance)	
Air:	Compatibility Group	
Peak Pressure		
Impulse -	Exudation	None
Energy		
Air, Con.ined:	PETRIN esters are listed in remainded and most of these esters have been	, ,
Impulse	have explosive properties.	
Under Water:	An infrared spectrophotometric	
Pegh. Pressure	was developed for the determination acetone content of PETRIN (ref c)	
Impulse	sample of PETRIN is dissolved in	
Snergy	and the volume increased to 25 mi	lliliters in
	a volumetric flask. The acetone the PETRIN solution is determined	
Underground: Peak Pressure	in a 0.5 absorption at 5.82	mm cell. A
Impulse	double beam method is used with a cell containing chloroform and ac	
Energy	PETRIN. The quantity of the latte	
Absolute Viscosity, poises:	carefully adjusted to give a good	belance be-
Temp, 17°C 14.8	tween the test sample and reference the strong PETRIN peak at 6.02 at	
23°C 4.3 28°C 3.0		····
38°C 1.2	Heat of:	
	Explosion, callum	1204

Explosion, cal/gm

1204

Preparation:

с(сн ⁵ он) [†] +	знио з	H ^S SO [†]	OHCH ⁵ c(CH ⁵ MO ³ , ³	+	3H2 ()
pentaerythritol	nitric scid	sulfuric acid	pentaerythritol trinitrate		water
MW 136	MW 63	MW 98	MW 271		MW 18

The earlies procedure used for the manufacture of PETRIN was that developed at Alleghany Ballistics Laboratory. In this process, called the "A process," 80% HNO; and the solid pentaerythritol were charged to the reactor and 80% H₂SO₄ was added slowly at a rate to permit control of temperature at 0° to 5°C. This mixture was held for a 2-1/2-hour reaction period, then drowned in water and filtered to give a cake containing both the tri- and tetra-nitrates of pentaerythritol. The cake was dissolved in acetone and neutralized in solution with ammoniu carbonate, after which the PETN and precipitated by the addition of water. After filtration, the PETRIN was recovered from the filtrate by stripping off the solvent under vacuum. Yields by this process averaged about 40%.

An improved process, called the "B process," used the same primary reaction procedure but a different work-up procedure. After the reaction holding period, water was added to dilute the mixed acid and the batch was extracted in situ with methylere chloride. The organic layer was separated, neutralized with aqueous sodium bicarbonate, and stripped of methylene chloride under vacuum to yield the product directly. Yields by this process were about 50% and quality of the product was much improved over that of the "A process."

The "C process," currently in use, involves essentially the simultaneous synthesis and extraction of PETRIN from the reaction mixture. Methylene chloride approximately equal to the total weight of the other components is added to the reaction mixture before the sulfuric acid. After a satisfied time following the addition of sulfuric acid, the solvent is removed and replaced by fresh solvent one or more times. The combined extracts are neutralized and concentrated. Because of their initially relatively large volume, PETN __s_ be removed by filtration from the concentrated PETRIN solution before the final solvent is stripped. Yields by this process have been 60% to 65%.

Origin:

The nitration products of pentaerythritol or its derivatives containing not more than three NO₂ groups were petented for use as explosives, propellants or ignition materials in 1936 (German Patents 638,432 and 638,433; CA 31, 1212 (1937)).

A process in which pentaerythritol monoacetate was converted to pentaerythritol trinitrate monoacetate, which was then sapenified under carefully controlled conditions to PETRIN, was reported in 1954 (N. S. Marans, D. E. Elrick and R. F. Preckel, J Am Chem Soc 70, 1304). THRIN was also prepared by the nitration of pentaerythritol with a mixture of 80% HMO₃ and 80% H₂SO₄ in 1955 (A. 7. Camp, N. S. Marans, D. E. Elrick and R. F. Preckel, J Am Chem Soc 77, 751).

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Pentserythritol Trinitrate (PETRIN)

References:54

- (a) Robm and Haas Company, Redstone Arsenal Division, Process for the Manufacture of Pentaerythritol Trinitrate Monoscrylate and Petrin Acrylate Propellants, 12 Mar. 1956.
- (b) E. Berlow, R. H. Barth and J. E. Snow, The Pentaerythritols, ACS Monograph No. 136, p. 65, Reinhold Publishing Corporation, New York, 1958.
- (c) R. H. Pierson, An Infrared Spectrophotometric Method for Determination of Acetone Content of Pentaerythritoltrinitrate, U.S. Havel Ordnance Test Station Report ROTE 1877, MAYORD Report No. 5649, 3 February 1958.

⁵⁴See footnote 1, page 10.

Pentaerythritol Trinitroacrylate (PETRIN Acrylate) [Trinitroxypentaerythritol Acrylate]

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Composition:	Melecular Weight: (C8H ₁₁ N ₃ O ₁₁) 325
C 29.5	Oxygen Belence:
H 3.4 CH2CNO2	CO ₂ %5¼12
т 3 сн ⁵ = сл-со ⁵ сн ⁵ с-сн ⁵ оио ⁵	-12
N 12.9	E ensity: gm/cc
0 54.2 CH20NO2	Melting Point: *C 78 to 79
C/H Ratio 0.239	Freezing Point: *C
Impact Sensitivity, 2 Kg Wt:	Beiling Point: *C
Bureau of Mines Apparatus, cm Sample Wt 20 mg	Refrective Index, no
Picatinny Aisenal Apparatus, in.	
Sample Wt, mg	n _m
	n _m
Priction Pendulum Test:	Vacuum Stability Test:
Steel Shoe	cc/40 Hrs, at
Fiber Shoe	90°C
Riffe Bullet Impact Test: Trials	100°C
•	120°C
% Explosions	135°C
Partials	150°C
Burned	200 Grem Bomb Send Tert:
Unaffected	Sand, gm
Explosion Temperature: °C	Sensitivity to Initiation:
Seconds, 0.1 (nu cop used)	Minimum Detonating Charge, gm
1	Mercury Fulminate
5	Lead Azide
10	Tetryl
15	Ballistic Morter, % TNT:
20	Trougi Test, % TNT:
75°C International Host Test: % Loss in 48 Hrs	Plate Deat Test:
The state of the s	Niethod
100°C Most Test:	Condition
% Loss, 1st 48 Hrs	Confined
% Loss, 2nd 48 Hrs	Density, gm/cc
Explosion in 100 Hrs	Brisance, % TNT
Flammability Index:	Detenci'na Rate:
	Confinement
Hygroscopicity: % N11	Condition
74.	Charge Diameter, in.
Volatility:	Density, gm/cc
·	Rate, meters/second

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Pentaerythritol Trinitroscrylate (PETRIN Acrylate)

regmentation Test:	Shaped Charge Effectiveness, TNT	== 100 :	
90 mm HE, M71 Projectile, Let WC-91:	Glass Cones St	eel Concs	
Density, gm/cc	Hole Volume		
Charge Wt, Ib	Hole Depth		
Total No. of Fragments:	Color:	White	
For TNT		HIII CG	
For Subject HE .	Principal Uses: Ingredient of	composite	
3 inch HE, M42A1 Projectile, Let KC-5:	rocket propel	lants ·	
Density, gm/cc			
Charge Wt, Ib			
Total No. of Fragmonts:	Method of Leading:		
For TNT For Subject HE			
	Looding Density: gm/cc		
agment Velocity: ft/sec			
At 9 ft At 251/4 ft	Storage:		
Density, gm/cc			
	Method Dry at tempe	ratures below melting point	
est (Reletive to TNT):	Hazard Class (Quantity-Distance)		
Air:	Compatibility Group		
Peak Pressure			
Impulse	Exudation	None	
Energy			
Air, Conficad:	. Heat of:		
Impulse	Combustion, _i./gm	292 3	
Ada dan Salanan	Explosion, callem	791	
Under Woter: Peak Pressure			
im ulse			
Energy			
Underground:			
Peak Pressure			
Impulse Energy			
Carry			

Pentaerythri a irinitroscrylate (PETRIN Acrylate)

(a) Preparation: HOCH2C(CH2NO3)3 $CH^5 = CHCOCI$ с₆н₅и(сн₃)₂ pentaerythritol trinitrate (PETRIN) acrylyl chloride dimethyl aniline MW 271 MW 90.5 MW 121 $(o^{5}NOCH^{5})^{3}CCH^{5}OCCH = CH^{5}$ c₆H₅N(CH₃)₂HC1 € pentaerythritol trinitrate monodimethylanine acrylate (PETRIN acrylate) MW 325 hydrochloride

The original synthesis for PETRIN acrylate employed trifluoroacetic anhydride and glacial acrylic acid as the acrylation agent for PETRIN. These two materials were charged to a reaction vessel and the initial reaction was controlled by the slow addition of PETRIN at a temperature of 10° to 15°C. Following a period of one hour, the batch was drowned in water, precipitating the PLIRIN acrylate. This solid was separated by filtration, dissolved in chloroform, and neutralized in solution with sodium bicarbonate. The product was then crystallized during a period of 16 hours at 0°C and dried under vacuum to remove traces of solvent. The yield for this process was about 60%.

A significant improvement in yield (to about 74%) and purity (approximately 96%) was realized by the substitution of methanol for chloroform and crystallization of the product from the solution without neutralization, residual acid being removed by washing the filter cake with water.

Because of the high cost and hygroscopic nature of trifluoroacetic anhydride, a new process, based on dimethylaniline and acrylyl chloride, was considered. This process is currently under development in one Rohm and Haas Chemical Processing facilities and is not considered optimum. Yields averaged 46% and product purities averaged 93.5%.

PETRIN Acrylate Propellants:

PETRIN acrylate could be used as a monopropellant because it has a specific impulse of 214 lb-sec/lb and a burning rate of 0.2 in/sec. The addition of an exidizer increases both the impulse and burning rate.

A composition which presently appears most promising is as follows:

	Compos1	tion NM
PETRIN acrylate (> 97% purity), %	34.3	(binder)
Triethylene glycol frinitrate, %	11.8	(plasticizer)
Glycol diacrylate, %	2.9	(crosslinker)
Ammonium perchlorate, %	51.0	(oxidizer)
Hydroquinone, %	0.014	(polymerization inhibitor)

Measured specific impulse 238 lb-sec/lb, at density of 1.3.

Reference:55

(a) Rohm and Haas Company, Redstone Arsenal Division, Process for the Manufacture of Pentaerythritol Tetranitrate Monoacrylate and Petrin Acrylate Propellants, 12 March 1956.

⁵⁵See footnote 1, page 10.

Pentolite, 50/50; 10/90

Composition:			Molecular Weight:	50/50 265	10/90 234
		[Oxygen Belence:		
PETN 50	10	1	CO ₂ %	-42	-68
TNT 50	90	l	co %	- 5	-21
101)0	,~		Density: gm/cc	1.65	1.60
		j	Melting Point: °C		76
C/H Ratio		Ī	Freezing Point: *C		
Impect Cereltivity, 2 Kg Wt: Bureriu of Mines Apparatus, ci	50/50 m 34	10/90 65	Boiling Point: *C		
Somple Wt 20 mg	_		Refrective Index, no		
Picatinny Arsenal Apparatus,	in. 12 15	14	n _s		
Sample Wt, mg	15	10	n ₂₀		
Friction Pendulum Test:			Vecnum Stability Test:	50/50	10/90
Steel Shoe	Un	affected	cc/40 Hrs, at		
Fiber Shoe	ប្រធ	affected	90°C		
			100°C	3.0	3.0
Riffe Bullet Impact Test: 25 Tri	ols, 50/50		120°C	11+	11+
Explosions 7	6 2		135°C		
Portials 2			150°C	••	
	0	1	900 C B C 4 T		
	8		200 Grem Bemb Send Test: Sond, gm	55.6	49.5
- Charrected					
Explosion Tumperature:	·c, 50/50		Sensitivity to Initiation:		<u>50/50</u>
Seconds, 0.1 (no cap used)	290		Minimum Detonating Ch	arge, gm	
_	26€		Mercury Fulminate		0.19*
	220	ļ	Lead Azide		0.13*
	50#		Tetryl *Alternative initiation	ng charges	
	197		Sallistic Morter, % TNT:	(a)	126
20 >	190	Ì	Trauzi Test, % TNT:	(b)	122
75°C International Host Test:				(c)	
% Loss in 48 Hrs			Plate Dent Test: Method	(0)	Б
			Condition		Cast
100°C Heat Test:	<u>50/5</u>	_	Condition		No
% Loss, 1st 48 Hrs	0.0	o	-		1.66
% Loss, 2nd 48 Hrs	0.:	2	Density, gm/cc		121
Explosion in 100 Hrs	No	ne	Brisance, % TNT		
Flemmability Index: Will not	continue to	hurn	Detenation Rate:		lion e
Assessment and a service of the serv	continue so	541.1	Confinement		Cast
Mysessessicity: 04.	0/50 10	/90	Condition		
Hygrescopicity: % 2 30°C, 90% RH N	one N	one	Charge Diameter, in.		1.0
Voletility:			Density, gm/cc		1.66
·			Rate, meters/second		7465

Pentolite, 50/50: 10/40

	0/50 Decemposition Equation: ast Oxygen, atoms/sec	
	00 (Z 'sec)	
	Heat, kilocalorie/mole	
Wax, gm	(AH, kcal/mal) Temperature Range, °C	
	.65 Phase	
Density, gm/cc 1.60		
Heat of: Combustion, cal/gm	Armor Plate Impact Test: 50	/50
Explosion, cal/gm	1220 60 mm Morter Projectile:	
Gas Volume, cc/gm		.70
Formation, cal/gm	Aluminum Fineness	
Fusion, cal/gm		
	500-lb General Purpose Bombs:	
Specific Heat: cal/gm/°C	Plate Thickness, inches	
	,	
	1	
	$\frac{n_4}{n_4}$	
	11/4	
	134	
Surning Rate: cm/sec		
Livy 36%	Romb Drop Test:	
Thermal Conductivity:	T7, 2000-th Semi-Armor-Piercing Bomb vs Con	erato:
cal/sec/cm/°C	17) 2000-m Sermi-Minist-1 mining noung 40 min	
Coefficient of Expansion:	Max Sufe Drop, ft	
Linear, %/°C	500-lb General Purpose Bomb vs Concrete:	
Volume, %/°C	Height, ft	
	Trials	
Herdness, Mohs' Scele:	Unarfected	
	Low Order	
Young's Modulus:	High Order	
E', dynes/cm²	Trigger writer	
E, lb/inch²	1000-lb General Purpose Bomb vs Concrete:	
Density, gm/cc		
	Height, ft	
	-2200 Trials	
Density, gm/cc	1.65 Unoffected	
Vapor Pressure:	Low Order	
°C mm Mercury	High Order	

Pentolite, 50/50; 10/90

Fragmentation Test:	<u>50/50</u>	Sheped Charge Effectiveness, TNT = 1 <u>50/50</u> 10/90 50/50	90: 25/75
90 mm HE, M71 Projectile, Let WC-1) 1:	Gloss Cones(1) Steel (
Density, gm/cc	1.65	Hole Volume 157 105 149	119
Charge Wt, Ib	2.147	Hole Depth 116 116 131	119
Total No. of Fragments:		Color	v-vhite
For TNT	703	Color: Yello	4111 06
For Subject HE	963	Principal Uses: Shaped charges,	hureting
3 inch HE, M/12A1 Projectile, Let KC-	5:	charges, demolit	
Density, gm/cc	1.65	"	
Charge Wt, Ib	0.872		
Total No. of Fragments:		Adah ad ad b andhan	
For TNT	514	Method of Leading:	Cast
For Subject HE	6 50		
		Looding Density: gm/cc	50/50 10/90
Fragment Velocity: ft/sec			1.65 1.60
At 9 ft At 251/2 ft	2810 2580	Sterege:	
Density, gm/cc	1.66	Method	Dry
			•
Blest (Relative to TNT):	(e)	Hazard Class (Quantity-Distance)	Class 9
Ale:		Compatibility Group	Group I
Peak Pressure	105	S. data	
Impulse	107	Exudation	
Energy		Compatibilities and his Made 2	
Air, Confined:		Compatibility with Metals:	
Impulse		Dry: Copper, brass, aluminum magnesium-aluminum alloy, mild	
		with acid-proof black paint, and	d mild steel
Under Weter:		plated with copper, cadmium or	
Peak Pressure		affected. Zinc plated steel is affected.	only slightly
Impulse			
Enurgy		we': Stainless steel, alumin steel conted with acid-proof bloom	
Underground:		not sife ted. Copper, brass, m	gnesium, mag-
Peak Pressure		nesium-aluminum alloy, mild stee	
Impulse		steel plated with copper, cadmit nickel are slightly affected.	AM, ZIAC OF
Energy		Effect of Temperature on	(h)
Eutectic Temperature, OC:	76	Rate of Detonation:	50/50
gm PETN/100 gm TNT			-54 21
76°C	13.0		.67 1.66 +70 7440
95°c	28.3	Mate, m/ sec	10 1440

Pentolite, 50/50; 10/90

Preparation:

Pentolite is manufactured by either the slurry method or coprecipitation of PETN and TNT. In the slurry method PETN, in water, is stirred and heated above 80°C. TNT is added and when molten, it coats the particles of PETN. The slurry is cooled with rapid stirring and the separated granules are collected on a filter and dried below 75°C.

In opprecipitation, PEIN and INT are dissolved separately in acctone. The solutions are mixed and the explosives are precipitated simultaneously by pouring the mixed solution into cold water under vigorous agitation. The precipitated solid is collected on a filter and dried in air.

Origin:

Standardized during World War II, with the 50-50 PETN/INT mixture being the more important for bursting charges and booster-surround charges.

References: 56

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 57%6, 27 December 1945.
- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
 - (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDE/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) W. R. Tomlinson, Jr., Elast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (f) Eastern Laboratory, du Pont, Investig.: on of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-ORD-5723.
- (g) Eastern Laboratory, du Pont, investigation of Cavity Effect, Final Report, Contract W-672-ORD-5723, E. Lab, du Pont, 18 September 1943.
- (h) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.
 - (i) Also see the following Picatinny Arsenal Technical Report on Pentolite:

<u>o</u>	1	2	3	4	2	<u>6</u>	7	8
1360 1420 1570	1291 1451 1651	1212 1262 1372	1133 1193 1213 1363	1284 2004	1325	1436 1466 1796	1477 1677 1737	1388 1598 1668 1838

⁵⁶See footnote 1, page 10.

PETN (Pentaerythritol Tetranitrate)

Composition:		Molecular Weight: (C5H8	N ₄ 0 ₁₂)	316
0NO ₂		Oxygen Velence:		
		CO ₂ %		-10
н 2.5 ^{СН} 2		CO %		15
N 17.7 02NO-CH2-C-CH2	-cno ₂	Density: gm/cc Cr	ystal	1.77
o 60. 8 cH ₂		Melting Point: °C		141
C/H Ratio 0.134 0NO ₂		Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C		
Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in Sample Wt, mg	17 6 16	Refrective Index, no		
Friction Pendulum Test:		Vacuum Stability Test:		
Steel Shoe Cr	eckles	cc/40 Hrs, at		
	affected	90°C		
		- 100°C		0.5
Riffle Sullet Impact Test: 5 Trials *		120°C		11+
%		135°C		114
Explosions 100		1		
Partials 0		150°C		
Burned 0		200 Grem Bomb Sand Test:		
Unoffected 0 *4.80% moisture in samples		Sand, gm		62.7
Explosion Temperature: °C		Sensitivity to Initiation:		
Seconds, 0.1 (no cap used) 272		Minimum Detonating Ch	arge, am	
1 244		Mercury Fulminate		0.17*
5 Decomposes 225		Lead Azide		0.03*
10 211		1		•
15		Tetry! *Alternative initiating	ng charge	8.
20		Ballistic Morter, % TNT:	(a)	145
FEOC Indon-Air-of Mana Trus		Trouzi Test, % TNT:	(b)	173
75°C International Heat Test: % Loss in 48 Hrs	0.02	Plate Lent Test:	(c)	
	J.0L	Method		A
100°C Heat Test:		Condition		Pressed
% Loss, 1st 48 Hrs	0.1	Confined		Yes
% Loss, 2nd 48 Hrs	· -	Density, gm/cc		1.50
	0.0	Brisance, % TNT		129
Explosion in 100 Hrs	None			
Flammability Index: Will not continue	e to burn	- Detenation Rate: Confinement		None
,		1		None
Hygroecopicity: % 30°C, 90% RH	0.0	Condition		Pressed
		Charge Diameter, in		1.00
Volatility:	0.0	Density, gm/cc		1.70
	V. ()	Rate, meters/second		8 300

PETN (Pentaerythritol Tetranitrate)

Booster Sensitivity Test: Condition	(c) Pressed	Decemposition Equation: (e) (e) (f) (f) (23.1 (20.6 1023.1
Tetryl, gm	5	(Z/sec) Heat kilocalurie/male 47.0 50.9 52.3
Wax, in. for 50% Detonation		Heat, kilocalurie/male 47.0 50.9 52.3 (ΔH, kcal/mal)
Wax, gm	3	Temperature Range, °C 161-233 108-120 137-157
Density, gm/cc	1.6	Phase Liquid Solid At melt
Heat of: Combustion, cal/gm	1960	Armor Plete Impact Test:
· · · · · ·	1 3 85	
Explosion, cal/gm	790	60 mm Morter Projectite:
Gas Volume, cc/gm	383	50% Inert, Velocity, ft/sec
Formation, cal/grn	303	Aluminum Fineness
Fusion, cal/gm		500-lb General Purpose Bombs:
Specific Hest: cal/gm/°C	(d)	
		Plate Thickness, inches
Room Temperature	0.26	
		1
		11/4
		11/2
		13/4
Eurning Rete:		
cm/sec		Bomb Drop Test:
Thermal Conductivity: cal/sec/cm/°C		T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:
Coefficient of Expansion:		Max Safe Drop, ft
Linear, %/°C		500-lb General Purpose Bomb vs Concrete:
Volume, %/°C		Height, ft
		Trials
Herdness, Mohs' Scele:	1.9	Unaffected
		Low Order
Young's Modulus:		High Order
E', dynes/cm²		1
E, lb/inch²		1000-lb General Purpose Bamb vs Concrete:
Density, gm/cc		
		—— Height, ft
Compressive Strength: Ib/inch ²		Trials
		Unaffected
Vaper Pressure:		Low Order
°C mm Mercury		High Order

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PETN (Pentaerythritol Tetranitrate)

Fregmentation Test:	Shaped Charge Effectiveness, TNT = 1	90:				
99 man HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel (Hole Volume Hole Depth	Cones				
Total No. of Fragments: For TNT	Color:	White				
For Subject HE						
3 Inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib	Class A - Detonating fuse an	Principal Uses: Class A - Detonating fuse and boosters Class B - Priming compositions				
Tetel No. of Fregments: For TNT For Subject HE	Mathod of Loading:					
ror subject the	Leading Density: gm/cc ps: x	103				
Fregment Velocity: ft/sec At 9 ft	1.37 1.58 1.64 1.71 1.7	0 40				
At 251/s ft Density, gm/cc	Storage:	•• .				
	Me nod	Wet				
Blact (Reletive to TNT):	Hazard Closs (Quantity-Distance)	Class 9				
Air: Peak Pressure	Compatibility Group	Group M (wet)				
Impulse	Exudation	None				
Energy						
Air, Confined:	Bulk Modulus at Room Temperature (25°-30°C):	(1)				
Under Weter: Peak Pressure	Dynes/cm ² x 10 ⁻¹⁰ Density, gm/cc	4.60 1.77				
Impulse						
Energy						
Underground: Peak Pressure						
Impulse						
Energy						

Compatibility with Metals:

<u>Dry:</u> Copper, brass, aluminum, magnesium, magnesium-sluminum alloy, stainless steel, mild steel, mild steel coated with acid-proof black paint and mild steel plated with copper, cadmium, nickel or zinc are not affected.

Wet: Stainless steel is unaffected and aluminum only vary slightly so after prolonged storage. Copper, brass, magnesium, magnesium-aluminum alloy, mild steel, mild steel costed with acid-proof black paint and mild steel plated with cadmium, copper, nickel or zinc are affected.

Sensitivity of PETN to electrostatic discharge, joules; Through 100 Mesh: (g)

Unconfined Confined

0.06

Solubility, grams of PETN per 100 grams (%) of: (h)

	rethylene lcohol	Ace	tone	Ве	nzene	To	luene
°c	ž	<u>°c</u>	£	°c	纟	°c	2
0 20 40 60	0.070 0.195 0.115 1.205	0 20 40 60	14.37 24.95 30.56 42.68	0 20 40 80	0.150 0.450 1.160 7.900	0 20 40 60 80 100 112	0.150 0.430 0.620 2.490 5.850 15.920 30.900
Methyl acetate		Ether		8-Ethoxy-ethyl- acetate		Chlorobenzene	
°c	£	°c	½	<u>°с</u>	2	°c	2
20 30 40 50	13 17 22 31	0 2 0 3 ¹ 4•7	0.200 0.340 0.450	20 30 40 50	1.5 4.1 7.6 11.2	20 30 40 50	0.35 2.8 6.1 9.2

Ethylenedichloride		Methanol		Tetrachloroethane		<u>Carbon</u> tetrachloride	
<u>°c</u>	½	°c	<u> </u>	<u> 20</u>	<u>\$</u>	<u>°c</u>	2
10 30 50	0.9 1.5 2.6	20 40 60	0.46 1.15 2.6	20 30 40 50	0.18 0.27 0.40 0.58	20 30 40 50	0.096 0.108 0.118 0.121

AMCP 7	06-177	PEIN (PETN (Pentar v'aritol Tetran trate)					
Isoproranol		Isobu	Isobutanc)		Chloroform		TNT	
<u>°c</u>	£	°c	2	<u>°c</u>	£	<u>°c</u>	Z	
15	0.05	20	C 27	20	0.09	80	19.3	
20	0.0	30 40	0.31			85	25.0	
30 40	0.15	40	0.39			90	32.1	
40	0.36	50	0.52			95	39.5	
50	0.46					100	48.6	
						105	58.2	
	Eutetic of the		N-TNT is abo	out 13% PET	5	110	70.0	
	and 87% TNT at	76°C.				115	87.8	
						120	115	
						125	161	

Preparation:

(Nitroglycerin and Nitroglycerin Amplosives, Naoum)

8HCHO + CH3CHO + Cm(OH)2 \longrightarrow 2C(CH2OH)4 + Cm(HCOO)2 C(CH2OK)4 + 4HNO3 \longrightarrow C(CH2OHO2)4 + 4H2O

1. In this preparation 1940 gm of formsldehyde and 600 gm of aceteliehyde are dissolved in 90 liters of vater containing 1600 gm suspended slaked lime. The reaction is complete in about 3 weeks if agitated several times a day. The solution is filtered, the calcium formate precipitated with omalic acid, filtered off, and the water removed under reduced pressure. On cooling the mother liquor about 1200 gm crude pentaery-thritol, melting point 2350-2400c are obtained. Purification is resudily effected by stirring with a little alcohol, filtering and recrystallization from water.

2. To 400 cc of strong white nitric cid, are added 100 gm of pentaerythritol (through 50 mesh), at 5°C or below, under good about ition. After addition is complete stirring, at 5°C, is continued for 15 minutes. The mixture is drowned in 3 liters of ice-water, filtered, the product washed free of acid with water and then digested 1 hour in 1 liter of hot 0.5% sodium carbonate solution. The product is filtered, and recrystallized from acetone.

Origin:

PETN was known as an explosive in 1894 when it was proposed as an addition to smokeless powders to raise their flammability and case of combustion (German Patent 81,664 (1894). Modern methods of preparation are described by Vignon and Gerin (Compt rend 133, 590 (1901) and German Patent 265,025 (1912) and A. Stettbacher (Z ges Schiess - Sprengst frv 11, 112, 102 (1916) and 24, 259 (1929)). PETN was not used on a practical basis until after World War I.

Destruction by Chemical Decomposition:

PETN is a compose by dissolving in 8 times its weight of technical grade acetone and burning the solution i a shallow container. If preferred, where the acetone solution to 40° C, stir and add 7 parts by weight, to each part of PPTN, of a solution of 1 part sodium sulfide (Ma_2 S·9 H_2 O) in 2 parts water heated to 80°C. The agreeus solution should be added at such a rate that the acetone solution does not buil. After mixing is complete continue stirring for challed boxin.

PETN (Pentaerythritol **etranitrate)

References:57

- (a) L. C. Smith and F. G. Hyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Testu; Performance Tests. OSRP Report No. 5746, 27 December 1945.
 - (b) Ph. Naoum, Z ges Schiess Sprengstoffw, pp. 181, 229, 267 (27 June 1932).
 - (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
 - (d) International Critical Tables.
- (e) M. A. Cook and M. T. Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind & Eng Chem, (June 1956), pp. 1090-1095.
- (f; A. J. B. Robertson, "The Thermal Decomposition of Pentaerythritol Tetranitrate, Nitroglyceri:. Ethylenediamine Dinitrate and Ammonium Nitrate," J Chem Ind 67, 221 (1948).
- (g) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U.S. Dept of Int, Bureau of Mines, RI 3852, 1946.
 - (h) Various sources in the open literature.
- (i) W. S. Cramer, <u>Bulk Compressibility Data on Several High Explosives</u>, NAVORD Report No. 4380, 15 September 1956.
 - (j) Also see the following Picatinny Arsenal Technical Reports on PETN:

<u>o</u>	<u>1</u>	2	- 3	4	2	<u>6</u>	1	<u>8</u>	2
760 1170 1260 1290 1300 1320 1360 2380 1390 1430 1450 1570	1041 1311 1381 1451 1561 1611 1651	772 922 1182 1192 1212 1262 1342 1352 1372 1452	843 863 1063 1133 1253 1343 1493 1533	904 1274 1284 1414	1305 1325 1445 1705 1885 2125	1246 1276 1316 1376 1446 1456 1466 1556	407 527 857 1247 1517 1617 1737 1797	318 633 1238 1318 1388 1568 1568 1598 1830 2178	1429 1489 1489 1559 2179

^{*}See footsote 1, page 16.

Picramide (TNA) (2,4,6-Trinitroaniline)

Composition:	Aolecular Weight: (C6H4N4O6)	228
c 31.5	Oxygen Belense:	_
	CO ₂ %	-56
H 1.8 o_2 N \sim N o_2	CO %	-14
N 24.5	Density: gm/cc Crystal	1.76
o 42.2 NO ₂	Melting Point: °C	189 to 190
C/H Ratio 0.500	Freezing Point: 'C	
Impocr Sensitivity, 2 Kg Wt:	Boiling Point: *C Decomposes bef	ore boiling point
Bureau of Mines Apparatus, cm Sample Wt 20 mg	Refractive Index, no	
Picatinny Arsenal Apparatus, in. 23	n _m	
Sample Wt, mg 20		
	n ₂₀	
Friction Pendulum Test:	Vacuum Stability Test:	
Stee! Shoe	oc/40 Hrs, at	
Fiber Shoe	90°C	
Rifle Bullet Impect Tess: Trials	100°C	0.9
•	120°C	
% Explosions	135°C	
Partic's	150°C	
Burned	200 Grem Bomb Sand Test:	
Unaffected	Sand, gm	48.2
Explosion Temperature: °C	Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, gm	
5	Mercury Fulminate	0.30
10	Leod Azide	Ų. 3 0
15	Tetryl	
20	Ballistic Morter, % TNT:	100
	Treux! Test, % TNT:	107
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	
	Condition	
100°C Heet Test:	Confired	
% Loss, 1st 48 Hrs		
% Loss, 2nd 48 Hrs	Density, gm/cc	
Explosion in 100 Hrs	Brisance, % TNT	
A	Detonation Rate:	
Flemmability Index:	Confinement	Non e
AA 1 to 00	Condition	Pressed
Hygroscopicity: %	Charge Diameter, in.	0.5
	Density, gm/cc	1.72
Voletility:		

AMCP 706-177

Picramide (TNA) (2,4,6-Trinitroaniline)

Fragmentation Test:	Shaped Charge Effectiveness, TNT == 100:			
90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth			
Total No. of Fragments: For TNT	Color: Yel	Yellow		
For Subject HE 3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: High temperature heat resistant explosive			
Total No. of Fragments: For TNT	Method of Loading:	Pressed		
For Subject HE Fregment Velocity: ft/sec	Leading Density: gm/cc At 50,000 psi	1.72		
At 9 ft At 25½ ft	Storega:			
Density, gm/cc	Method	Dry		
Slest (Relative to TNT):	Hazard Class (Quantity-Distance)	Class 9		
Air: Peak Pressure Impulse Energy	Compatibility Group Exudation	Group I		
Air, Centined: Impulse Under Weter: Peok Pressure Impulse Energy	Solubility: Insoluble in water, slightly soluble alcohol and ether. Soluble in hot acetic acid, hot ethyl acetate and and acetone. Heat of:	glacial		
Underground: Peak Pressure Impulse Energy	Combustion, cal/gm (a) Explosion, cal/gm Formation, cal/gm (a)	2962 564 131		

Picramide (TNA) (2,4,6-Trinitroaniline)

Preparation:

Five grams of picryl chlumide were dissolved in 180 milliliters of absolute methanol. The solution was then satureled with anhydrous, gaseous ammonia. The time required was approximately 30 minutes. The amino derivative precipitated in 75% yield (3.5 gm) melting at 190° C (literature MP 189° C).

Origin:

Picramide (2,4 o-trinitroaniline) was first prepared in 1854 by Pisani who treated picryl chloride with am onium carbonate (CR 39, 853). The use of picramide, as a brisant explosive, was patended by Chemische Fabrik Griesheim 26 May 1894 (German Patent 84,628). Meisenheimer and Patzig reseted trinitrobenzene with hydroxylamine in cold alcohol solution to obtain picramide (Ber 39, 2534 (1906)). Witt and Witte obtained the compound by nitrating a solution of aniline in glacial acetic acid or concentrated H₂SO₄ at about 5°C with concentrated HNO₂ (Ber 41, 3091 (1908)). Holleman gives details of the prep ation from p-nitroaniline and from acetanilide (Rec trav chim 49, 112 (1930)).

Reference: 58

(a) William H. Rinkenbach, "The Heats of Combustion and Formation of Aromatic Nitro Compounds," J Am Chem Soc 52, 116 (1930).

⁵⁸See footnote 1, pag .0.

Picratol, 52/45

Composition:		Molecular Weight:	<u>236</u>
Explosive D 52		Oxygen Balance:	6 .
		CO. % CO %	-63 -19
INT 43			
		Density: gm/cc Cast	1.62
		Malting Point: 'C	
C/H Ratio		Freezing Point: "C	
Impact Sansitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	100+	Boiling Point: 'C	
Sample Wt 20 mg		Refractive Index, no	
Picatinny Arsenal Apparatus, in.	17 19	ns	
Sample Wt, mg	17	n _m	
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe	Unaffected	cc/40 Hrs,	
Fiber Shoe	Unaffected	20 ℃	
Rifle Bullet Impact Test: Trials		100°C	0.37
•		120 °C	0. 68
Explosions 0		135°C	
Partials 0		150 C	0.7
Burned 40		200 Gram Bemb Send Test:	
Unaffected 60		Sand, am	45.0
Explosion Temperature:	/	Sonsitivity to Initiation:	
Seconds, 0.1 (no cap used) 45		Min mum Detonating Charge, gm	
1 35 5 Decomposes 39		Mercury Fulminate	
5 Decomposes 28	-	Leaa Azide	0.20
10 26 15 26		Tetryl	0.0.
15 247 20 25		Ballistic Murter, % TNT: /13)	100
		Trouzi Tost, % TNT;	
75°C International Heat Test: % Loss in 48 Hrs	0.0	Plote Dent "ost: (:)	
		Method	:
100°C Hest Test:		Condition	8 €
% Loss, 1st 48 Hrs	0.0	Confined	Ge.
% Loss, 2nd 48 Hrs	0.0>	Density, gm/cd	1.13
Explosion in 100 Hrs	Non-e	Brisunce, % TNT	ţ(h)
Flammability Index:		Detenation Rate: (-)	
		Confinement	: +
Hygrescepicity: % 30°€, 30% R	4 0.02	Condition	# E '
		Charge Diameter, in)
Volatility:		Density, gm/cc	
		Rate, meters/second	1.0

Picratcl, 52/48

Fregmentation Test:		Shaped Charge Effectiveness, TNT = 10	y :
90 mm HE, M71 Projectile, Lot WC-9	1:	Glass Cones Steel Co	ones
Density, gm/cc	1.61	Hole Volume	
Charge Wt, Ib	2.075	Hole Depth	
Total No. of Fragments:		Color: Bros	wn-yellow
For TNT	703	Bron	MIT-YELLOW
For Subject HE	76 9	Principal Uses: AP, SAP projectiles	and bombs
3 inch HE, M42A1 Projectile, Let KC-!	S :	and the same of th	5 4.1 6 COMED
Density, gm/cc	1.61	j	
Charge Wt, Ib	0.850		
Total No. of Fragments:		Method of Loading:	Cast
For TNT	514	melines (* Essening.	Casc
For Subject HE	487		
		Loading Deveity: gm/cc	1.62
Fregment Velocity: ft/sec	0500		
At 9 ft At 2514 ft	2590 2320	Storage:	
Density, gm/cc	1.62		
		Method	Dry
Blast (Relative to TNT):		Hozard Crass (Quantity-Distance)	Class 9
Air:		Compatibility Group	Group I
Peak Pressure	100) _	
impulse	100	Exudation	None at 650
Energy			
		Preparation:	
Air, Confined:		Picratol is made by heating TW	T to about
Impulse		90°C in a steam-jacketed melt ke	
Under Weter:		sive D is added slowly, without pand the mixture stirred until un	
Peak Pressure		position. This slurry is cooled	
impulse		and poured into the appropriate	
Energy		component.	
Underground:		Origin:	
Peak Pressure		Developed during World War II	
Impulse		tive, "elt-loaded AP bomb and pro	ojectile fille
Energy		Booster Sensitivity Test:	(c)
Bomb Drop Test:		Condition	Cast 100
T7, 2000-15 Semi-Armor-Pierc	ing	Tetryl, gm Wax, in. for 50% Detonation	1.00
Bomb vs Concrete:		Density, gm/cc	1.63
		f	

Picratol, 52/48

References: 59

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
 - (b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (d) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.
 - (c) Also see the following Picatinny Arse: $\epsilon 1$ Technical Reports on Picratol:

 0
 5
 6
 I
 8
 9

 1470
 1885
 1466
 1737
 1838
 1729

 1796
 1797

 1956

⁵⁹See footnote 1, page 10.

Composition:		Molecular Weight: (C ₆ H	3 ^N 3 ^O 7)	229		
C 31.5		Oxygen Belence:		\		
	wa	CO ₂ %		-45 -3•5		
H 1.3 02N	No ₂					
N 18.3)	Density: gm/cc	Crystal	1.76		
0 48.9 Y		Melting Point: °C		122		
C/H Ratio 0.656	Freezing Point: °C					
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	85	Boiling Point: °C				
Sample Wt 20 mg	1.5	Refractive Index, no				
Picatinny Arsenal Apparatus, in. Sample Wt, mg	13 17	n ₂₅				
Time trying II		no				
Friction Pandulurs Test:		Vacuum Stability Test:				
Steel Shoe		cc/40 H·s, at				
Fiber Shoe		6. C				
Rifle Bullet Impact Test: Trials		100°C		0.2		
%		120°C		0.5		
Explosions		135°C				
Partials 60		150°C				
Burned 40		200 Grem Bomb Sand Test	:			
Unaffected 0		Sand, gm		48.5		
Explosion Temperature: "C		Sensitivity to Initiation:	_			
Seconds, 0.1 (no cap used)		Minimum Detonating Cl	harge, gm			
1 5 December 220		Mercury Fulminate		0.26*		
5 Decomposes 320		Lead Azide		0.24*		
10 15		Tetryi *Alternative initiati	ng charges.			
20		Ballistic Morter, % TNT:	(a)	112		
		Frouzi Test, % TNT:	(t)	101		
75°C Internetional Heat Test: % Loss in 48 Hrs	0.05	Plate Dent Test:	(c)			
70 Loss III 40 Firs	0.0,	Method		Α		
100°C Heat Test:		Condition		Pressed		
% Loss, 1st 48 Hrs	0.03	Confined		No		
% Loss, 2nd 48 Hrs	0.09	Density, gm/cc		1.50		
Explosion in 100 Hrs	Kone	Brisance, % TNT		107		
P		Detonation Rate:	(a)			
Flammability Index:		Confinement		Unconfin ed		
Hygroscopicity: % 30°C, 90% ldf) ol	Condition	Pressed	Cas		
пунгосорисну: № 30°С, 90% ВН	0.04	Charge Dameter, in.	.0	1.25		
Volatility:		Density, gri/cc	1.04	1.71		
		Rate, meters/second	>270	7350		

Picric Acid

Booster Sensitivity Test:		c)	Decomposition Equation:
Condition	Pressed	Cast	Oxygen, atoms/sec (Z/sec)
Tetryl, gm	10	5	Heat, kilocalorie/mole
Wax, in. for 50% Detonation			(AH, kcal/mol)
Wax, gm	2	0	Temperature Range, "C
Density, gm/cc	1.6	1.7	Phase
Heat of: Combustion, cal/gm	2	.72	Armor Plate Impact Test:
Explosion, cal/gm	10	000	60 mm Mortor Projectile:
Gas Volume, cc/gm		675	50% Inert, Velocity, ft/sec
Formation, cal/gm		245	Aluminum Fineness
Fusion, col/gm (a) Temperature, or		0.4 122	500-lb General Purpose Bombs:
Specific Heet: cal/gm/°C (e)			Disc. Third was to be
° <u>c</u>	٥	.235	Plate Thickness, inches
30	0	.258	1
30 60		. 282	114
90 120		. 310 . 337	11.2
100	·	, ,,,,	_ 13,
Burning Rate: cm/sec			Somb Drop Test:
Thermal Conductivity: (f) cal/sec/cm/°C Density, gm/cc	6.2½ x	10 ⁻¹⁴ 1406	17, 2000-th Semi-Armor-Piercing Bomb vs Concrete:
Coefficient of Expansion:			Max Safe Drop, ft
Linear, %/°C			500-lb General Purpose Bomb vs Concrete:
Volume, %/°C			Height, ft
Hardness, Mohs' Scale:	2	.1	Trials
115-Fuldes	٤	• •	Unaffected
Young's Modulus:			Low Order
E', dynes/cm²			High Order _
E, Ib/inch²			,,,,,,,
Density, gm/cc			1000-lb General Purpose Bomb vs Concrete:
			Height, ft
Compressive Strength: Ib/inch ²			Trials
			Unaffected
Vapor Pressure:			Low Order
°C mm Mercu	ry		High Order
195 2			
255 50			

Picric Acid

Fragmentation Test:	Shepad Charge Effectiveness, TNT = 100):			
90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, lb	Glass Cones Steel Cones Hole Volume Hole Depth				
Total No. of Fragments: For TNT	Color: Yell	ov			
For Subject HE 3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, lb	Principal Uses: Formerly projectile filler, now explosive admixture; and for the manufac are of Explosive D				
Total No. of Fragments: For TNT For Subject HE	Method of Loading: Pro	ssed			
Progress Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Louding Density: gm/cc psi x 3 5 10 12 15 1.40 1.50 1.57 1.59 1.6 Storage:	20			
Blest (Relative to TNT):	Hazard Class (Quantity-Distance)	Class 9			
Air: Peak Pressure Impulse Energy Air, Confined:	Compatibility Group Exudation	Group I			
Impulse Under Weter: Peok Pressure Impulse Energy Underground: Peok Pressure Impulse Energy					

Pierie Acid

<u>olubi</u>]	ity: grame	per 100	grems (%)	of: (g)					
3	ater	Alc	cohol	<u>Be</u>	nzene	<u>T</u>	oluene	Eth	er
<u>°c</u>	ž	°c	\$	<u>°c</u>	٤	°c	ž	<u>°с</u>	ž
0 20 40 60 80 100	0.85 1.17 1.88 2.98 4.53 7.1	0 20 40	1.9 5.9 12.0	20 40 60	~2 9.6 27.5 59	20 60	~13 ~30	20 34•7	~3 3.96
Chlo	roform	Ethyl	acetate		bon chloride	Pyz	dine	Acet	one
°c	ž	°c	ž	°c	£	°c	2	<u>°c</u>	<u> </u>
20 60	~6 ~6	20 30 40 50	42 50 58 69	20 60	~0.07 ~0.4	10 30 50	24 37·5 58	20 30 40 50	125 137 164 208
M	ethanol	Isop	ropyl elec	hol	Propano	1-1	Carbon d	isulfide	
<u>°c</u>	£	°c		ž	<u>°c</u>	2	<u>°c</u>	2	
0 20 40 50	14 19 31 41	10 30 50		6.4 9.8 5.5	0 20 40 50	2.4 3.3 5.4 7.4	20 30	0.12 0.16	
	tion: (Sum								
	6 + Hg(NO ₃) ₂				-	_		(1)
	5mem3 + m21				-	(NO3)5		(2)
с6н	5140 + 2140 -				C6H5N2NO3			(3 a)
CEH	5N2NO3 + H20	· ——			C ₆ H ₅ OH + N	s + HMO3		(3 b)
	50H + HNO3					+ н ⁵ 0			3c)
с6н	5 ^{NO} öxidati	on and	NO3 rearrangem	ent	SNC ⁶ H ⁷ OH			(4)
o ^S M	с6сн + ни о3		102		(0 ₂ N) ₂ C6H ₃	он + н20			5)
	и) ₂ с6н ³ он +							(6)

Picric Acid

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The two variables of greatest importance in this process are nitric acid concentration and the effective concentration of benzene (i.e., benzene dissolved in the expnitration solution). The optimal concentration of nitric acid is in the range 10.4 to 11.6 molar (or the equivalent of 50% to 55% by weight for pure acid). The acid concentration greatly influences the over all rate of reaction, below 10.4 molar the rate falls off rapidly, while above 10.4 molar the rates of both the expnitration reaction and various side reactions, such as direct nitration, increase rapidly. The range mentioned above seems, in general, to give the lowest proportion of neutral nitro-compounds to nitro-phenols with, at the same time, an adequate rate of expnitration. The expnitration solution must be fortified frequently, or, preferably, continuously with nitric acid. Strengths of nitric acid between 95% and 98% are best, due to the smaller increase in reaction volume than if weaker acid were used. The use of absolute nitric acid requires that its direct contact with liquid benzene be avoided.

The effective concentration of bearene is probably the most critical variable affecting the proportion of neutral nitro-compounds to nitrophenols and amounts of colored by-products. Saturation of the exymitration solution with bearene is undesirable and thus in batch processes slow bearene addition is preferable to the addition of it in one portion; in continuous processes where an excess of bearene is used the rate of agitation is important.

The concentration of mercuric nitrate catalyst does not appear to be a critical factor over a mainly wide range. Concentrations of 0.3% to 0.5 mole of mercuric nitrate per liter of oxymitratio, solution have been found to give satisfactory results in most cases.

A continuous process, known as the continuous addation process, works on the following cycle. The oxynitration solution is saturated with bendene by vigorous agitation with excess benzene at more temperature, the saturated solution is separated from excess benzene and direculated through a heated coil; it is then cooled to room temperature and agitat i again, with benzene, which extracts the organic product and resaturates the oxynitration solution. In evaluating this process, the rate of formation of dinitrophenol per liter of reacting solution in the coil is determined; To gm of dinitrophenol per liter per hour is representative performance. The dinitrophenol is, of course, nitrated to picric acid.

Origin:

Picric Acid was first prepared in 1771 by Woulff who found the reaction of nitric acid and indigo yielded a dye. Hausmarn isolated Picri Ar i in 1776 and studyed it further (Journal de physique 32, 165 (1780)). The proparation was studied by many chemists but in 1841 Laurent established its identity (Ann chim this III, 2, 221 (1841)). It was used as a yellow dye until Purpin, in 1865, proposed Picric of as a pursting charge for high explosive shell (French Potent 187,512). The British adopted disric Acid as a military explosive in 1868 under the mane of lyddite and other nations soon began to use it as the first melt-loaded high explosive. Mixtures of other explosives and Picric Acid were developed until it was gradually replaced by TMT about 1900. Today Pic ic Acid is used for the manufacture of Explosive D.

Destruction by Chemical Lecompositions

Pieric Acid is decomposed by dissolving in 25 times its weight of a solution made from 1 part sodium hydroxide and 21 parts sodium sulfide (Naph 9HgO) in 200 parts of water. Some hydrogen sulfide and ammonis are evolved.

References: 60

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Mircellaneous Sensitivity Tests; Performanc: Tests, OSRD Report No. 5746, 27 December 1945.
 - (b) Ph. Naoum, Z ges Schiess-Sprengstoffw, pp. 181, 229, 267 (27 June 1932).
 - (c) D. P. MacDougall, Methods of Fnysical Testing, OSRD Report No. 803, 11 August 1942.
- (d) G. H. Masserly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.
- M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.
 - (e) International Critical Tables.
- (f) E. Hutchinson, The Thermal Sensitiveness of Emplosives. The Thermal Conductivity Emplosive Materials, AC Report No. 2861, First Report, August 1942.
 - (g) Values taken from various sources in the open literature.
 - (h) Also see the following Picatinny Arsenal Technical Reports on Picric Acid:

<u>ī</u>	2	3	4	2	<u>6</u>	1	8	2
1651	132 582 1172 1352 1372	1363	694 764 874	65 425 1585	266 556 926 976 986 1446 1556	1347 1557	1118	15.9

⁶⁰See Cootnote 1, page 10.

Composition:		Molacular Weight:	310
~		Oxygen Salence:	
PEIN	81	CO: %	-74
A.3.4. A = A.17	• •	CO %	-31
Gulf Crown E 011	19	Doneity: gm/cc Hend tampe	1.35
		Melting Point: *C	
C/H Ratio		Freezing Point: *C	
Impact Sonitivity, 2 Kg Wt:		Boiling Point: *C	
Bureou of Mines Apparatus, (Sample Wt 20 mg	cm	Refrective Index, no	-
Picatinny Arsenal Apparatus,	, in. 11	T	
Sample Wt, mg	27	n <u>e</u>	
Friction Pendulum Test:		Vocuum Stability Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
		— 100°C	0.48
Rifle Bullet Impact Test: Tr	ials	120°C 16 hours	11+
	%	135°C	_
	0	150°C	,
	Ç.		
	0	200 Grcm Bomb Sond Test:	
Unaffricted 10	0	Sand, gm	41.6
Explosion Temperature:	·c	Sonsitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, g	m
1		Mercury Fulminate	0.20*
5 Decomposes*		Lead Azide	0.20*
10			
15		*Alternative initiating char	rges.
20 *No value obtained.		Ballistic Morter, % THT:	
75°C International Heat Test:		Treuzi Test, % TNT:	
% Loss in 48 Hrs		Plate Dent Test: (a) Method	В
1001C Mark Tari		Condition	Hand tamped
100°C Heat Test:		Canfined	No No
% Loss, 1st 48 Hrs	0.17	Density, gm/cc	
% Loss, 2nd 48 Hrs	0.00	1	1.33
Explosion in 100 Hrs	None	Brisance, % TNT	76
Flommobility Index:		— Detaration Rate: Confinement	None
		- Condition	Hand tamped
Hygrescepicity: % 30°C, 90	% RH 0.02		1.0
	,	Charge Diameter, in.	
Volatility:		Density, gm/cc	1.37
V COUNTRIEV:		Rate, meters/second	7075

Fragmentation Test:		Shaped Charge Effectivaness, TNT = 100:
90 mm HE, M71 Projectile, Let WG-	91:	Glass Cones Steel Cones
Density, ym/cc	1.33	Hole Volume
Charge Wt, Ib	1.723	Hole Depth
Total No. of Fragments:		Color:
For TNT	703	Catal:
For Subject HE	519	Principal Uses: Plastic demolition explosive
3 Inch HE, M42A1 Projectile, Let KC	.\$:	
Density, gm/cc	1.39	j
Charge Wt, Ib	0.735	
Total No. of Fragments:		Method of Londing: Hand tamped
For TNT	514	
For Subject HE	428	Leading Density: gm/\ta 1.35
Fragment Velocity: ft/sec At 9 ft		Leeding Density: gm/cc 1.35
At 251/2 ft		Storage:
Density, gm/cc		Mathod Dry
Blast (Relative to TNT):		Hazard Class (Quantity-Distance) Class 9
Air: Peak Pressure		Compatibility Group Group I
Impulse		Exudation
Energy		
Air, Coofined: Impulse		Origin: PIPE, a mechanical mixture of PETN and Gulf Crown E Oil, was developed in the United State during World War II.
Under Water: Pagk Pressure		
Impulse		References: 61
Energy		(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III-Miscellaneous
Underground: Peak Pressure		Sensitivity Tests; Perfor ance Tests, OSRI Report No. 5746, 27 December 1945.
Impulse		(b) S. Livingston, Properties of Explosive RIPE, PIPE and PEP-3, Picatinny Arsenal Techni
Energy		cal Report 1517, 24 April 1945.
Preparation:		1
PIPE is manufactured by simp mixing of PETN in oil.	ole mechanical	

⁶¹See footnote 1, page 10.

Plumbatol

Composition: %		Molocular Weight:	291
		Oxygen Belence:	
Lead Nitrate	70	CO ₂ %	-5.4
INT	30		+9.3
		Density: gm/cc Melting Point: *C	· · · · · · · · · · · · · · · · · · ·
C/H Ratio		Freezing Point: *C	
mpact Semitivity, 2 Kg Wt. Bureau of Mines Apparatus, cm		Boiling Point: *C	
Sample Wt 20 mg	13	Refractive Index, no	
Picatiwny Arsenal Apparatus, in. Sample Wt, mg	13 22	ng	
		n ₅	
Friction Pondulus: Test:		Vocuum Stability Test:	
Steel Shoe		cc/40 Hrs, at	
Fiber Shoe		90°C	
Riffe Bullet Impact Test: Trials		100°C	
•		120°C	
% Explosions		135°C	
Portials		150°C	
Burned		200 Grem Bomb Sand Test:	
Unaffected		Sand, gm	32.4
Explosion Temperature: 'C		Sensitivity to Initiation:	
Seconds, 0.1 (no cop used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5 Decomposes 238		Lead Azide	0.20
10 15		Tetryi	0.^0
20		Bellistic Morter, % TNT:	
		Trouzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test: Method	
00°C Heat Test:		Condition	
% Loss, 1st 4B Hrs		Confined	
% Loss, 2nd 48 Hrs		Density, gm/cc	
Explosion in 100 Hrs		Brisance, % TNT	
lemmebility Index:		Detonation Rate: (b)	
		Confinement	
Tygroscopicity: %		Condition	
		Charge Diameter, in.	
/olatility:		Density, gm/cc	2.39
		Rate, meters/second	4350

Plumbatol

fragmentation Test:	Shoped Charge Effectiveness, TNT = 100:
90 mm HE, MT? Projectile, Let WC-91: Density, gm/cc Charge Wt, lb	Glass Cones Steel Cones (a) Hole Volume 11 ¹ Hole Depth 103
Total Me, of Progments: For TNT For Subject MF	Color: Light yellow
3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib	Principal Utana
Total No. of Fragments: For TNT For Subject HE	Mathrd of Loading: Cast
Pregment Velocity: ft/sec	Leading Density: gm/cc
At 9 ft At 251/4 ft Density, gm/cc	Storage: Method Dry
Bleet (Relative to TNT):	Hazard Class (Quantity-Distance) Class 9
Air: Peak Pressure Impulse Energy	Compatibility Group Group I
Air, Confined: Impulse Under Weter:	Origin: An explosive containing 70% lead nitrate and 50% TNT has been used in Belgium under the name of "Marcarite."
Peak Pressure Impulse Energy	References: 62 (a) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation Cavity Effect with Explosive Composition, MI
Undergreund: Pook Pressure Impulse Energy	(b)es Dictionary of Applied Chemistry. Fourth Edition, Vol IV, Longmans, Greand Company, London - New York - Toronto, p. 464.
Preparation: Plumbatol is manufactured by simple mechanical mixing of lead nitrate in molten TWT.	

⁶²See footnote i, page 10.

PLX (Liquid)

Composition:			Melocular Weight:	100 61	25/5
%	100	*	Oxygen Belence:	91	91
Ni trome thene	100	95	CO ₂ %	-39	-48
Ethylenediamine	/-	5	CO %	-13	-21
*The mixture 95/5 Niti is designated PLX (for sive). See note under	or Piceting	y Liquid Explo-	Density: gm/cc	1.14	1.12
arvey. See noor und	or Scorage.	'	Melting Foint: *C	-2 9	
C/H Ratio			Freezing Point: °C		
Impact Sanshivity, 2 Kg W Bureau of Mines Appara		100 95/5 100+ 100+	Builing Point: "C	101	
Sample Wt 20 mg	-		Refrective Index. no		
Picatinny Arsenal Appar	ratus, in.	20 20	n o		
Sample Wt, mg		20 20	ng		
Friction Fundalum Test:			Vocuum Stability Test:		
Steel Shoe	Ur	affected	cc/40 Hrs, at		
Fiber Shoe	Ur	affected	90°C		
			100°C		
Rifle Bullet Immeet Test:	LO Trials	5 Trials	120°C		
	%	\$	135°C		
Explosions	0		150°C		
Partials	0	O			05/5
Burned	Ö	C/	200 Gram Bomb Sond Tool	. <u>100</u> 8.1	<u>95/5</u>
Unaffected	100	100	Sand, gm	8.1	50.6
Explosion Temperature:	•c	°C	Sensitivity to Indition:	,	
Seconds, 0.1	100	<u>95/5</u>	Minimum Detonoting C	harge, gm	
1			Mercury Fulminate		
5	430	430	Lead Azide		
10			Tetryl		
15				3 al.	
20			Saffistic Morter, % TNT:	134	
75°C International Heat To			Trougi Toot, % PA	127	
% Loss in 48 Hrs			Plate Dest Test: Method		
100°C Heat Test:			Condition		
% Loss, 1st 48 Hrs			Confined		
% Loss, 2nd 48 Hrs			Density, gm/cc		
Explosion in 100 Hrs			Brisance, % TNT		
			Detonation Rate:	1/32"*	1/32"*
Flommobility Index:				Glass	Glass
				Liquid	Liquid
Hygrescepicity: %			Charge Diameter, in.	1.25	0.94
				1.14	1.12
Volatility:			1	6 21C	6165

PLX (Liquid)

Beester Sensitivity Test: Kitromethane Condition	Decemposition Equation: (d) <u>Nitromethque</u> Oxygen, atoms/sec 10 ¹⁴
Tetryl, gm	(Z/sec) Heat, kilocalarie/male 56.6
Wax, In. for 50% Detonation	(AH, kcol/mol)
Wax, gm	Temperature Ronge, °C 380-430
Density, gm/cc	Phose Geneous
Nest ef: (a) Combustion, col/gm 2630	Armer Plata Impact Test:
Explosion, cat/gm	40 mm Mortur Projectile:
Gas Volume, cc/gm	50% Inert, Velocity, ft/sec
Formation, cal/gm -348	Aluminum Fineness
Fusion, col/gm Vaporization, cal/gm 149	500-lb General Purpose Bembe:
Specific Heat: col/gm/°C (b)	Diana Thisteness tendens
C = 0.4209 ~ 0.00076t + 0.0000061t ² for 15°C to 70°C	Plate Thickness, inches
	1
	11/4
	11/2
	1%
Burning Rate: cm/sec	
	Romb Drop Test:
Thermal Conductivity: cal/sec/cm/°C	17, 2000-th Sami-Armor-Planting Bomb vs Contrate:
Coefficient of Expansion:	Max Safe Drop, ft
Linear, %/°C	300-th General Propose Semb vs Concrete:
Volume, %/°C	Height, ft
	Trials
Mardness, Mohs' Scale:	Unaffected
Yanna'a Madahan	Low Order
Young's Medulus:	High Order
E', dynes/cm² E. lb/inch²	
Density, gm/cc	1000-lb General Purpose Bomb vs Concrete:
	Height, ft
Compressive Strongth: Ib/inch ²	Trials
	Unaffectea
Vapor Pressura: (c)	Low Order
°C mm Mercury	High Order
70 258	
85 ###	

PLX (Liquid)

Light yellow Light yellow ield clearing Pumping 100 95/5 1.14 1.12 as stored separately; y when ready to use Distonce)
Pumping 100 95/5 1.14 1.12 as stored separately; y when ready to use
Pumping 100 95/5 1.14 1.12 as stored separately; y when ready to use
100 95/5 1.14 1.12 as stored separately; y when ready to use
100 95/5 1.14 1.12 as stored separately; y when ready to use
100 95/5 1.14 1.12 as stored separately; y when ready to use
100 95/5 1.14 1.12 as stored separately; y when ready to use
1.14 1.12 s stored separately; y when ready to use
1.14 1.12 s stored separately; y when ready to use
s stored separately; y when ready to use
y when ready to use
y when ready to use
y when ready to use
-Distance)
100 95/5 0.5 0.063
es: (<)

0.748 0.625
0.533
ild steel and duriron
s brass.

Origin:

Hitromethene has been known since 1872 (Kolbe, J prakt Chem (2) 5, 427 (1872), but was available only as a laboratory product until it appeared as an industrial chemical in 1940. A number of patents have been issued for nitromethene produced as a by-product of the citration of propens (U. S. Patent 1,967,667 (1934); British Patent 3,707 (1937); and Canadian Patent 371,007 (1938).

The development of nitromethane liquid explosives was based on information that nitromethane is sensitized to initiation and propagation of deconation by the addition of various emines. This study made at Picatinny Arsenal in 1945 indicated that mixtures of nitromethane with 5% of ethylenediamine, n-butyl-amine, or morpholine ghowed considerable promise for application in mine-field clearance (L. H. Eriksen and J. W. Rowen. PATR No. 1965, 17 September 1945).

References:63

- (a) D. E. Holcomb and C. F. Dorsey, "Thermodynamic Properties of Nitropareffine," Ind Eng. Chem 41, 2788 (1949).
- (b) J. W. Williams, "A Study of the Physical Properties of Nitromethane," J Am Chem Soc 47, 2644 (1925).
 - (c) L. Medard, "Explosive Properties of Nitromethane," Mem poudr 33, 125 (1951).
- (d) T. L. Cottrell, T. E. Graham and T. J. Heid, "The Thermal Decomposition of Mitramethanes," Transactions of the Faraday Society 47, 584 (1951).
- (e) F. Bellinger, H. B. Friedman, W. H. Bauer, J. W. Eastes and W. C. Bill, "Chemical Propellants: Stability of Monomitromethane," Ind Engr Chem 40, 1320 (1948).
 - (f) Also see the following Picatinny Arsenal Technical Reports on Nitromethane:

<u>o</u>	1	. 3	5 `	<u>6</u>	1	<u>8</u>	2
1660	1681 1831	2113	1565 -	2016	1747	1708	1619

⁶³See footnote 1, page 10.

Potassium Dinitrobensfurozan (KDRBF)

Co. yposition:	Weleanler Meight: (KCEHFHFOE)	225
** NO2	Oxygen Belence: CO ₂ % CO %	-60 -18
0 36.3 C2N NO K	Density: gm/cc	2.21
к 14.8	Melting Point: *C Explodes	510
C/H Ratio 0.416	Presning Point: *C	
Supert Sensitivity, 2 Kg Wt: Bureou of Mines Apparetus, cm	Solding Point: *C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3; (1 1b wt) 6 Sample Wt, mg	Refrective Index, no no no no	
Frietico Pendulum Test:	Yacuum Stubility Toot:	
Steel Shoe Explodes	cc/40 Hrs, at	
Fiber Shoe Explodes	90°C	
Riffle Bullet Empact Test: Trials	120°C	
%	135°C	
Explosions	150°C	
Portiols		
Burned Unaffected	200 Green Bench Send Test: Sand, gm 44.8 Black poster fine 9.5	43.6
Exploiten Temperature: "C	Squaltivity to Initiation:	
Seconds, 0.1 (no cop used)	Minimum Detariating Charge, gm	
	Mercury Fulminate 0.30	0.20
5 250 10	Lead Axide	0.10
1. (1. (1. (1. (1. (1. (1. (1. (1. (1. (Tetryl	
20	Sellistic Mortor, % TMT:	
	Trausi Yest, % THT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Seet Test: Method	
100°C Heat Test:	Condition	
% Loss, 1st 48 Hes 0.03	Confined	
% Loss, 2nd 48 Hrs 0.05	Density, gm/cc	
Explosion in 100 Hrs Hone	Brisance, % TNT	
Floremebility Index:	Determent Confinement	
Mygressepicity: % 30°C, 75% RH 0.11 30°C, 90% PH 0.27	Condition Charge Dierseter, in.	
V:/atility:	Density, gm/cc	
·	Rate, misters/second	

Potassium Dinitrobensfuroman (XDMBF)

December Semaltivity Tests		Decemposition Equation:
Condition		Onygen, etome/sec
Tetryl, gm	٠,	(Z/sec) Heat, kilocolorie/mole
Wax, in. for 50% Detonation		(AH, kcol/mol)
West, gm		Tomperature Range, *C
Density, gm/cc		Phase
Mont of:	2209	Armer Plate Impest Test:
Combustion, col/gm		•
Explosion, cal/gm	725 604	60 mm Morter Projectile:
Gas Volume, cc/gm	004	50% Inert, Velocity, ft/sec
Formation, col/gm		Aluminum Fineness
Fusion, cal/gm	N.S.	500-th General Purpose Bembe:
Specific Meet: col/gm/°C (b)		
<u>°c</u>	125,7	Plate Thickness, inches
	A 23.77	
-50 0	0.217 0.217	. 1
25	0.217	1%
50	0.217	11/4
		- 1%
Burning Rate: cm/sec		
On/ sac		Somb Drop Test:
Thermal Canductivity: cal/sec/cm/°C		17, 2000-th Souni-Armor-Pleasing Bomb vs Concepte:
		Max Safe Drap, ft
Coefficient of Expension:		Max sale orap, it
Linear, %/°C		500-16 General Purpase Bomb vs Constate:
Volume, %/°C		Height, ft
		Triols
Mardness, Mahe' Scale:		Unaffected
Manager A. A. A. A. A.		Low Order
Young's Medulus:		High Order
E', dynes/cm²		1
E, Ib/inch ^a		1888-lb General Purpase Bumb vs Cancrete:
Density, gm/cc		M. J. A. 40
Compressive Strength: Ib/inch ²		- Height, ft
Compression on outgoing 10/ IIII/		Triols
		Unaffected
Vapor Pressure: mm Mercury		Low Order
THIS MERCURY		High Order
		}

Potassium Dinitrobenzfuroxan (KDNBF)

·		
90 mm ME, M71 Projectile, Let WC-91:	Glass Cones Steel Cone	15
Density, gm/cc	Hole Volume	
Charge Wt, ib	Hole Depth	,
Total No. of Fragments:	Color: Orange t	o home
For TNT	Canal Canal	OTOWN
For Subject HE	Principal Uses: Primary ex	plosive
2 Inch HE, M42A1 Projectile, Let KC-5:		
Density, gm/cc		
Charge Wt, Ib		
Total No. of Fragments:	Method of Leading: Pres	sed
For TNT		
For Subject HE	Leading Density: gm/cc psi x	
Fragment Valueity: ft/sec	10 20 30 40 1.63 1.77 1.81 1.86	80 1.98
At 9 ft		
At 251/4 ft	Storage:	
Dersity, gm/cc	Method	Wet
Blook (Refetive to TNT):	Hazard Class (Quantity-Distance)	Class 9
Air:	Compatibility Group Gr	oup M (web)
Peak Pressure	Exudation	
impulse		
Energy		
Air, Confined:	Solubility in Wat ., gm/100 gm solvent, at:	
Impulse		
	30°c	0-245
Under Weter:	Stab Sensitivity:	
Peak Pressure	Density Firing Point (inc	
. Impulse	gm/cc 0/5 50%	100%
Energy	1.63 73 79 1.77 66 75	84
Underground:	1.77 66 75 1.81 42 48	83 64
Peak Pressure	1.86 12 15	1.8
Impulse	1.93 11 17	21
Energy	1.98 7 11	14
	Activation Energy:	
	kcai/mor	82.6
	Induction Period, see	3.5-10

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Potassium Dinitrobenzfurowan (KDRBF)

Preparation of Potassium Salt of 4,6-dinitrobensfurozan: (a)

Benishrowan, made by the reaction of ortho-nitroaniline cast alkaline sodium hypochlorite, was discolved in 6 parts of 96% sulfuric acid and nitrated at 5° -20°C with a 4 to 1 sulfuric-nitric acid mixture. The salt was prepared by neutralization of the 4,6-dinitrobensfurousn with potassium bicarbonate followed by recrystallization from hot water. The product forms in small golden orange plates which explode at 210°C.

Origin:

The potassium salt of 4,6-dinitrobenzfuroxan was first prepared in 1899 by von P. Drost (Ann 307, 56 (1899)).

References: 64

- (a) R. J. Gaughran, J. P. Picard and J. V. R. Kaufman, "Catribution to the Chemistry of Bensfurous Derivatives," J Am Chem Soc 76, 2233 (1954).
- (b) C. Lenchitz, Ice Calorimeter Determination of Enthalpy and Specific Heat of Eleven Organometallic Compounds, PATR No. 2224, November 1955.
- (e) Also see the following Picatinny Arsenal Technical Reports on Potassium Dinitro-

<u>2</u> <u>3</u> <u>6</u> <u>9</u> 2 2.22 2093 2146 2179

⁶⁴See footnote 1, page 10.

Composition:		Moleculer Walght:	252	
RDX	30	Oxve "elence;		
-		2.4	-45 - 9	
Tetryl	50	• Vensity: gm/cc	1.68	
TMT	20	Mel - Point: 'C Eutectic	67	
C/H Ratio		Freezing Point: 'C	- •	
Impest Sensitivity, 2 Kg Wt: Byveau of Mines Apparatus, cm	111	Beiling Point: *C		
Sample Wt 20 mg Picationy Arsenal Apparatus, in.		Refrective Index, na		
Sample Wt, mg		n <u>u</u>		
-		no no		
Frietlen Pendulum Test:		Vacuum Stability Test:		
Steel Shoe		cc/40 Hrs, at		
Fiber Shoe		90°C	3.0	
Riffe Bullet Impact Test: Trials		120°C	3.0	
. %		135°C		
Explosions 20		150°C	٤	
Partials 20				
Burned 0		200 Gram Bomb Sánd Test:	-1 0	
Unaffected 60		Sand, gm	54.8	
Emplosion Temporature: *C		Sensitivity to Initiation:		
Seconds, 0.1 (no cop used)		Minimum Detonating Charge; gm	0.00*	
		Mercury Fulminote	0.23* 0.22*	
10		Lead Azide	U. ZZ"	
15		*Alternative initiating charges.		
20		Ballistic Morter, % TNT: (a)	132	
		_ Trousi Test, % THT:		
75°C International Heat Test: % Loss in 48 Hrs		Plate Don? Test: (b)		
2 COS #1 TO F #13		Method	В	
100°C Heat Test:		Condition	Cast	
		Confined	No	
% Loss, 1st 48 Hrs		Density, gm/cc	1.68	
% Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs				
		Brisance, % TNT	127	
% Loss, 2nd 48 Hrs Explosion in 100 Hrs		Detenation Rate:		
% Loss, 2nd 48 Hrs		Detenction Rate: Confinement	None.	
% Loss, 2nd 48 Hrs Explosion in 100 Hrs Planmability Index:		- Detenation Rate: Confinement Condition	None.	
% Loss, 2nd 48 Hrs Explosion in 100 Hrs	0.00	Detenction Rate: Confinement	None.	

Fragmentation Test:		Shoped Charge Effectiveness, TNT ==	: 100:
90 mm HE, M71 Projectile, Let WC-91:		Glass Canes Stee	I Conss
Density, gm/cc	1.64	Hole Volume	
Charge Wt, Ib	2.180	Hole Depth	
Total No. of Fragments:		Color:	
For TNT	703		
For Subject HE	999	Principal Uses: Land mines and o	lemolition
3 inch HE, M42A1 Projectile, Let KC-5:		charges	
Density, gm/cc	1.63		
Charge Wt, Ib	0.864		
Total No. of Fragments:		Method of Looding:	Cast
For TNT	514		
For Subject HE	685	Landan Banku anda	1.68
Freement Velocity: ft/sec		Leeding Density: gm/cc	1.00
At 9 ft At 25½ ft	2690 2460	Storage:	
Density, gm/cc	1.64	1	
		Method	Dry
Blest (Relative to TNY):		Hazard Class (Quantity-Distance)	Class 9
Ain	(d)	Compatibility Group	Group I
Peak Pressure	111	6 . 1.1 .	
Impulse	109	Exudation	Brudes at 65°C
Energy			
Air, Confined:		Preparation:	
Impulse		The ternary explosive system RDK, tetryl and TNT is prepare	
Under Weter:		appropriate weight of water-we tol (40/60) previously melted	et RDK to a tetry
Peak Pressure		jacketed melt kettle. Heating	
Impulse		are continued until all the W	iter is evaporate
Energy		and the mixture is uniform in PTX-1 is also prepared by addi	
Underpreund: Pack Pressure		Composition B.	
Impulse		Compatibility with Metals:	
Energy		Dry: Aluminum, mild steel	not affected.
Booster Sensitivity Test: (c)		Wet: Aluminum, mild steel	not effected.
Condition Pross			
Tetryl, gm 100			
Wax, in. for 50% Detonation 1.9 Density, gm/cc 1.6	1.82 51 1.68	1	

Origin:

The possibility of employing ternary mixtures to obtain emplosives having greater power and higher brisance than binary mixtures was suggested by the analysis of Russian 76 mm, armor piercing high emplosive rounds (PATR No. 1311, 17 July 1943). The Russian type ternary explosives, based on the composition and laboratory studies of such mixtures, were indicated to be effective pressed fillers. In conducting a preliminary study of castable ternary emplosive mixtures suggested by the Russian fillers, a mixture consisting of REM/tetryl/TET, designated PTx-1 was developed which had emplosive and physical properties offering considerable advantage for military applications (PATR No. 1350, 27 October 1943; and 1379, 11 January 1944).

A PTX-3 composition, prepared by the addition of Haleite to 40/60 tetrytol, also offered promise but limited to applications where the charge would not be required to withstand storage at 65° C without equilation.

References: 65

- (a) L. C. Smith and E. G. Ryster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
 - (b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. (33, 11 Augur.: 1942.
- (c) L. C. Smith and S. R. Walton, A Consideration of RDE/Wax Mixtures as a Substitute for Tetryl in Boostars, NOL Memo 10,303, 15 June 1949.
- (a) W. R. Tomlinson, Jr., Blast Effects of Bomb Emplosives, PA Tech Div Lecture, 9 April 1948.
 - (e) Also see the following Picatinny Arsenal Technical Reports on PTX-1:

<u>o</u>	2	3	<u>6</u>	I	2
1530	1402	1623	1466 1506	1437	1379 14 2 9 1469

Composition:	Melecular Weight: 244 243
RIM 44 - 41 PEIN 26 - 26	CO ₂ % -33 -36 CO % -3 - k
TMT 26 - 33	Density: grn/cc 1.70
181 20 5 33	Mailing Point: °C Butectic 75
C/H Ratio	Freezing Point: *C
Impact Sandkirky, 2 Kg Wt: Bureou of Mines Apporatus, cm 35	Builing Palat: *C
Bureau of Mines Apparatus, cm 35 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Refrective Index, no. no. no.
Frietien Fendulum Test: Steel Shoe Crackle Fiber Shoe	Vecuum Stability Test: cc/40 Hrs, at 90°C
Riffe Buillet Impact Test: Triols	100°C 2.6
95 Explosions 60	120°C 11+
- ·	150°C
Partials 0 Burned 0	
Unaffected 40	200 Gram Bomb Sand Test: Sand, gm 56.9
Explication Temperature: *C Seconds, 0.1 (no cop used)	Scooltivity to Initiation: Minimum Detonating Charge, gm
1	Mercury Fulminate 0-23
5 10	Lead Azide 0.00
15	Tetryl 0.00
20	Bellistic Mortor, % TNT: (a) 138
	Trougi Test, % TNT:
75°C International Heat Test: 96 Loss in 48 Hrs	Plate Bent Test: (b) Method B
100°C Heat Test:	Condition Cast
% Loss, 1st 48 Hrs	Confined No
	Density, gm/cc 1.71
% Loss, 2nd 48 Hrs	Brisance, % TNT 141
% Loss, 2nd 48 Hrs Explosion in 100 Hrs	
	Detenation Rate: Confinement None
Explosion in 100 Hrs Planmability Index:	Confinement None Condition Cast
Explosion in 100 Hrs	Confinement None Condition Cast

Fragmentation Test:		Shaped Charge Effectiveness, TNT = 1	0 0:
90 mm HE, M71 Projectile, Let W	C-91:	Glass Cones Steel (Cones
Density, gm/cc	1.68	Hole Volume ~ 130	
Charge Wt, to	2.226	Hole Depth	·
Total No. of Fragments:		Calor:	
For TNT	703	-	
For Subject HE	1128	Principal Uses: Shaped charges	
3 Inch HE, M42A1 Projectile, Let N	(C-5:	Fragmentation ch	arges
Density, gm/cc	1.70		
Charge Wt, Ib	0.897		
Total No. of Fragments:		Method of Localing:	Cast
For TINT	514	manage or concerns.	
For Subject HE	750		
Construct Water to Annual Construction		Leeding Density: gm/cc	1.70
Fregment Velocity: ft/sec At 9 ft At 25½ ft	3020 2650	Storege:	
Density, gm/cc	1.70	Method	Dry
Elast (Relative to THT):		Hazard Class (Quantity-Distance)	Class 9
Ain	(a)	Compatibility Group	Group I
Peak Pressure	113	Sunda ton	None at 65°C
Impulse	113	Excude rion	node at 0) t
Energy	*-		
Ale, Confined:		Preparation:	
Impulse		The ternary explosive system RDX, PETN and TMT is prepared b	
Under Weter: Peak Pressure		appropriate weight of water-wet tolite (30/70) previously melte	RDX to a pen- d in a steam-
Impulse		jacketed melt kettle. Heating	and stirring
Energy		are continued until all the wat and the mixture is uniform in c	omposition.
Underground: Pack Pressure		PTX-2 is also prepared by addin PETN to RDX Composition 3.	g water-wet
impulse		Compatibility with Metals:	
Energy		Dry: Aluminum, mild steel n	ot affected.
Booster Sensitivity Test:	(c)	Wet: Aluminum not affected.	
Condition Tetryl, gm	Pressed Cast		
Wax, in. for 50% Detonation Density, gm/cc	1.87 2.32 1.70 1.61		

Origin:

The possibility of employing ternary mixtures to obtain explosives having greater power and higher brisance than binary mixtures was suggested by the analysis of Russian 76 mm, armorpherein; high explosive rounds (PATR Ho. 1311, 17 July 1543). The Russian type ternary explosives, based on the composition and laboratory studies of such mixtures, were indicated to be effective pressed fillers. In conducting a preliminary study of castable ternary explosive mixtures suggested by the Russian fillers, a mixture consisting of RDM/PETM/DET, designated PTK-2 was developed which had explosive and physical properties offering considerable advantage for military applications (PATR Ho. 1360, 27 October 1943; and 1379, 11 January 1944).

A PTX-4 composition, prepared by the addition of Haleite to 30/70 Pentolite, also offered provide but because of border-line stability in accelerated stability tests, PTX-4 must be proven by long term storage to be acceptable for use in standard ammunition.

References: 66

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, ORD Report No. 5746, 27 December 1945.
 - (b) D. P. MacDougall, Methods of Physical Testing, OSED Report No. 803, 11 August 1942.
- (c) L. C. Smith and S. R. Walton, A Consideration of RDE/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Merco 10,303, 15 June 1949.
- (d) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, FA Tech Div Lecture, 9 April 1948.
 - (e) Also see the following Picatinny Arsenal Technical Reports on PTX-2:

<u>o</u>	2	3	<u>4</u>	2	<u> 6</u>	<u>8</u>	2
1530	1482	1483 1623	1414	1445	1466	1838	1379 1429 146)

66See footnote 1, page 10.

Composition:		Meleculer Weight:	21.7
		Oxygen Belonce:	
ROX	90	CO ₂ %	-37 -10
Polywinyl Acetate	8	∞ %	
Dibutylphthalate	5	Denotity: gm/cc Pressed	1.60
		Sartaning Point; oc	98
C/H Retio		Freezing Point: *C	
mpost Sensitivity, 2 Kg Wt:		Boiling Point: *C	
Bureau of Mines Apparatus, cm Sample Wt 20 mg	39	Refractive Index, no	
Picatinny Arsenal Apparatus, in.	9		
Sample Wt, mg	13	n <u>a</u>	
		n _o	
frietlen Pendulum Test: Steel Shoe	Crackles	Vectors Stebility Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
FIDEN 3708		100°C	0.45
Rifle Bullet Impact Test: 5Trick *		120°C	0.88
Explosions 20		135°C	
		150°C	11+
Partials 0 Biumed 60		and Company Country Co	
		200 Gram Bomb Sand Test: Sand, gm	58.5
*IOO trials at -46°C - Uneffect	ted		,,
Explosion Temperature: *C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detanating Charge, gm	
1 330 5 Decomposes 375		Mercury Fulminate	0.22
10 265		Lead Azide	V. 22
15		Tetryl	
20		Ballistic Mortor, % TNT:	
		Trousi Test, % TNT:	
75°C laternetional Heat Test: % Loss in 48 Hrs		Plate Dent Test: Method	
10016 Hard Tools		Condition	
100°C Heat Test:	0.10	Confined	
% Loss, 1st 48 Hrs	0.16	Density, grn/cc	
% Loss, 2nd 48 Hrs Explosion in 100 Hrs	-	Brisance, % TNT	
Explosion in 100 ins	None	- Detenation Rate:	
Flommobility Index:		Confinement	None
		Condition	Cas+
Hygrescepicity: % 30°C, 90≸ RH	0.20	Charge Diameter, in.	1.0
		Density, gm/cc	1.60
Veletility: 55°C, vacuo, 6 hrs			

Fregmentation Test:	Shaped Charge Effectiveness, TNT = 100;		
90 min HE, M71 Projectile, Let WG-91: Danelty, gm/cc Charge W1, Ib	Glass Cones Steel C Hole Volume Hole Depth	iones	
Total No. of Fragments: For TNT	Color:	White	
For Subject HE 3 Inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, ib	Principal Uses: Demolit	ion charges	
Total No. of Fragments: For TNT	Method of Looding: Pressed or extrud		
For Subject HE	Looding Density: gm/cc	1.60	
Programm Velocity: ft/sec At 9 ft At 25½ ft	Storage:		
Density, gm/cc	Method	Dry	
Sleet (Relative to THT):	Hazard Class (Quantity-Distance)	Class 9	
Air: Paak Presure Impulse Energy	Compatibility Group Exudation No.	Group I	
Air, Confined: Impulse Under Weter: Pack Pressure	Plasticity: -40°C 25°C	Cracked	
Impulse Energy			
Undergrand: Peak Pressure Impulse Energy			

Preparation:

Explosive PVA-4, a semi-plastic composition of Canadian origin, consists of 90% RDX, 8% polyvinyl acetate and 2% dibutylphthalate (DEP). This formulation was developed by Rr. Suthurland of Shawinigan Chemicals, Ltd. In evaluating various types of polyvinyl acetate commercially available in the United States, a type obtained from Union Carbide and Carbon, under the industrial named or designation "AYAT" was the most promising coating for RDX in the proportions RDX/FVA(AYAT)/DEP 92/6/2.

A practical method of preparing this composition was by the addition of a solution of the coating agent to an aqueous RDK slurry. Based on the quality of the product and the pellet densities obtained, a procedure of adding an acctone solution of PVA + DBP to a hot water slurry of RDK, under agitation, was adopted as standard.

References: 67

(a) See the following Picatinny Arsenal Technical Reports on PVA-4: 1532 and 1634.

⁶⁷See footnote 1, page 10.

the control of the co	· ~ · · · · · · · · · · · · · · · · · ·	
Composition:	Molecular Weight: (C2H3MC3) n	(89) _n
C 27	Oxygen Beleace: Cu., % CO %	-45 - 9
H 3.4 (H ₂ C-CH-OHO ₂) _n	Density: gm/cc	
0 54	Making Point: *C (Soft Pb)	50
C/H Ratio 0.203	Freezing Point: *C	
Impact Sensitivity, 2 Kg Wt: 14.86/M	Boiling Point: *C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Refrective Index, no. no. no. no.	
Friction Fundation Test: Steel Shor Crackles Fiber Shoe Unaffected	Vector Stability Test: cc/40 Hrs, at 90°C	
Riffie Belligt Impact Yest: Tricks	100°C 16 hours	11+ 11+
Explosions %	135°C 150°C	 *
Portiols Burned Unaffected	200 Green Bomb Sand Test: Sand, gm	49.9
Explosion Temporatyre: °C Seconds, 0.1 (no cap used) 1 5 265 10	Sensitivity to Initiation: Minimum Detanating Charge, gm Mercury Fulminate Lead Azide Tetryl	
20	Ballistic Morter, % TNT:	
	Treat Test, % THT:	
75°C International Mont Yest: % Last in 48 Hrs	Plate Dent Test: Method	
160°C Heat Test: % Loss, 1st 48 Hrs 1-9	Condition Confined	
% Loss, 2nd 48 Hrs 2.1	Density, gm/cc	
Explosion in 100 Hrs None	Brisance, % TNT	
Planmobility Index:	Detenation Rate: Confinement Condition	
HygrescepleBy: % 30°C, 90% RH 0.62	Chr ge Diameter, in.	
Veletility:	Density, gm/cc Rate, meters/second	

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PVM (Polyvinyl Mitrate)

Progmontation Test:	Shoped Charge Officeltrezone, TMT == 100:	
90 mm HE, M71 Projectile, Let WC-91:	Glass Cones Steel Cones	Į
Density, gm/cc	Hote Volume	- 1
Charge Wt, ib	Hole Depth	1
Total No. of Fragments:	Colors	\dashv
For TNT		ı
For Subject HE	Principal Vaso:	7
3 Inch HE, MESAT Projectile, Let KC-5:		1
. Density, gm/cc	• •	1
Charge Wt, th		
Total No. of Progmosts:	Method of Leading:	\dashv
For TNT		
For Subject HE		
	Leeding Symby; gm/cc	ı
Programme Volumenty: Pt/sec		
At 7 ft At 25½ ft	Sterage:	7
Density, gm/cc		- (
· · · · · · · · · · · · · · · · · · ·	. Method	-
Start (Salative to THT):	Hazard Class (Quantity-Distance)	
Alm	Competibility Group	1
Pook Pressure		•
Impulse	Exudation	ļ
Energy		-
Alt, Confined:	65.5°C KI Test:	
longuitee	Minutes 60+	
Under Waters	134.5°C Heat Test:	
Pack Pressure	Selmon Pink 20	i
Impulse	Red Punes 25	
Energy	Explodes 300+	
Undergreeund:	240-Hour Hydrolysis Test:	
Peak Pressure	\$ HMO ₃ 5.07	1
Impulse	Heat of:	1
Energy		
	Combustion, cal/gm 2960	
	Explosion, cal/gm 900 Gas Volume, cc/gm 836	
•	330	
		1
	·	

PVN (Polyvinyl Nitrate)

Preparation:

Polywinyl alcohol is mixed with acetic anhydride. The mixture is cooled to -5° C and the nitric acid is added slowly while the mass is being stirr d. The temperature is controlled by the rate of acid addition so that when all the acid has been added the temperature does not rise above 20° C.

When the nitration is complete, the wixture is drowned by allowing a fine stream . The ayrupy liquid to flow from the nitrator and mix intimately with a large stream of water. This causes the product to precipitate in a fine state.

The finely divided precipitate is purified by boiling in frequent changes of water.

Origin:

The first preparation of polyvinyl nitrate was reported in 1929 by solution of polyvinyl alcohol in concentrated sulfuric acid and treatment with nitrating acid at a temperature not over 50°C. (German Patent 537,303). Later patents issued relative to polyvinyl nitrate included U. S. Patent 2,118,487 (1938) and German Patent 737,199 (1943).

Composition:	Metecular Weight: 230
%	mercener warpun:
	Oxygen Belence:
RDX 85	CO, % -70
Gulf Crown E Oil 15	CO % -35
•	Density: gm/cc Hand tamped 1-37
	Molting Peint: *C
C/H Ratio	Freezing Point: *C
spect Sensitivity, 2 Kg Wt:	Boiling Polur: *C
Bureou of Mines Apparatus, cm 53 Sample Wt 20 mg	Refrective Index. nº
Picetinny Areenal Apparatus, in. 13	-
Sample Wt, mg 25	ο
	n <u>s</u>
Foliation Pandulum Test:	Vector Stebility Test:
Steel Shoe Unaffected	cc/40 Hrs, at
Fiber Shop. Unaffected.	90°C
Date Date Investor	100°C 0.34
Riffe Pullet Impact Test: Trials	120°C 0.56
%	135°C
Explosions 0	150°C
Partials 0	
Burned 0	200 Gram Bomb Sand Test:
Unaffected 100	Sand, gm 40-1
Explosion Temperature: "C	Sonsitivity to Initiation:
Seconds, 0.1 (no cop used)	Minimum Detonating Charge, gm
1	Mercury Fulminate
5 Decomposes; no value obtained	Lead Azide 0.20
10	Tetryl
15	Sollistic Morter, % TNT: (a) 118
20	Treast Test, % TNT:
75°G International Heat Test:	Plate Door Test: (b)
% Loss in 48 Hrs	Method B
	_
160°C Heat Test:	Condition Hand tamped
% Loss, 1st 48 Hrs 0.03	Confined No
% Loss, 2nd 48 Hrs	Density, gcn/cc 1.37
Explosion in 100 Hrs None	Brisance, % TNT 85
Planmability Index:	Detenation Rate:
remaining libers:	Confinement None
	Condition Hand tamped
	* · · · · · · · · · · · · · · · · · · ·
Hygrseespickly: % 30°C, 90% RH 0.04	Charge Diarneter, in. 1.0
Figgracespicity: % 30°C, 90% RH 0.04 Velocities:	* · · · · · · · · · · · · · · · · · · ·

	~ ~~~			
Fragesagtation Test:	Market Service	Shapet Charge Effective	enecs. TNT == 100:	-
90 mm HE, M71 Foojectits, Lot WC	:-91:	Glass (Cones Steal Cone	• •
Density, gm/cc	1.36	Hole Volume		
Chasss W !b	1.786	Hote Depth		
	1.4		4.2 24	
Total Ma. of Fragments:				***
For TNT	703	Color:		White
For Subject PIE	592		* * *	
LOL Winders ME		Principal Uses: Plat	tic demolition	explosive
3 treb HE MAZAT Projectile, Lat K	C-S:			
Density grovec	1.42	.0		
Charge Wt, Ib	0.756			
A CONTRACTOR OF THE CONTRACTOR	The second second			
Total No. of Fragmetter		Shathad of Landler-	Hand ta	
For TN	514	Mathed of Looding:	Nang Ca	
For Subject ME	501			
on surport the		Leading Density: gm/c	:	1.37
			-	
Fragment Velocity: ft/sec	2650			
At 9 ft At 251/4 ft	2650 2370	Storage:		
Density, gm/cc	1.395	_		
	- 47.7	Method		Dry
			ala. Olasan 1	Class 9
Bleet (Reletive to TNT):		Hazard Class (Quan	rity-Lastonce	7
A4		Compatibility Group		Group I
Air: Peok Pressure			at 85°C in 30	hre
Impulse		Enudation None	at 95°C in 48	hrs
Energy		Equ	les at 105°C in	48 hrs
er angy				
Air, Confined:		Origin:		
Impulse		RIPE, a mechanic	al mixture of RI	X and Gulf
		Crown E Oil, was de	eveloped in the	United State
14- A W-A		during World War I	Į.	
Under Weter:		l		
Peak Pressure		References		
Peak Pressure Impulse		(a) L. C. Smith	and E. G. Eyste	r, Physical
Peak Pressure		(a) L. C. Smith Testing of Explosi	ves, Pert III -	Miscellaneou
Peak Pressure Impulse Energy		(a) L. C. Smith Testing of Explosi Sensitivity Tests;	ves, Part III - Performance Tea	Miscellaneou
Peak Pressure Impulse Energy Underground:		(a) L. C. Smith Testing of Emplosi Sensitivity Tests; port No. 746, 27	ves, Pert III - Performance Tes December 1945.	Miscellaneou its, OSRD Re-
Peak Pressure Impulse Energy Underground: Peak Pressure		(a) L. C. Smith Testing of Emplosi Sensitivity Tests; port No. *746, 27	ves, Part III - Performance Tes December 1945. ugall, Methods o	Miscelleneousts, OSRD Re-
Peak Pressure Impulse Energy Underground: Peak Pressure Impulse		(a) L. C. Smith Testing of Emplosi Sensitivity Tests; port No. 746, 27	ves, Part III - Performance Tes December 1945. ugall, Methods o	Miscelleneousts, OSRD Re-
Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy		(a) L. C. Smith Testing of Explosi Sensitivity Tests; port No. **Ab, 27 (t) D. P. MacDo Testing, OSRD Repo (c) Also see th	Performance Tee Performance Tee December 1945. ugail, Methods ort No. 303, 11 A e following Pice	Miscellaneou its, OSRD Re- of Physical august 1942.
Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Preparation:		(a) L. C. Smith Testing of Emplosi Sensitivity Tests; port No. *746, 27	Performance Tee Performance Tee December 1945. ugail, Methods ort No. 303, 11 A e following Pice	Miscellaneou its, OSRD Re- of Physical august 1942.
Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	imple mechanical	(a) L. C. Smith Testing of Explosi Sensitivity Tests; port No. **Ab, 27 (t) D. P. MacDo Testing, OSRD Repo (c) Also see th	Performance Tee Performance Tee December 1945. ugail, Methods ort No. 303, 11 A e following Pice	Miscellaneou its, OSRD Re- of Physical august 1942.

68See footnote 1, page 10.

Silver Azide

Composition:	Melecular Weight: (AgN ₃) 150	
и 28.0	Cxygen Belence:	
	CO ₂ % -5	
Ag 72.0	CO % -5	
Ag-N=N = N	Density: gm/cc Crystal 5.1	
	Melting Point: "C (a) 251 Decomposes rapidly above melting point to	
C/H Ratio	Freezing Point: "C silver and nitrog	en
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 6	Boiling Point: 'C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3	Refrective Index, no	
Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 18	n ⊆	
	n _s	
Friction Pendulum Test: PA Small Apparetus	Vacuum Stability Test:	
Steel Shoe Detonates	cc/40 Hrs, at	
Fiber Shoe Detonates	90°C	
Rifle Beilet Impect Test: Trials	100°C	
%	120°C	
Explosions	135°C	
Portials	150°C	
Burned	200 Gram Bomb Sand Test:	
Unoffected	Sand. am (b)	
		_
Explacion Temperature: 'C	Sensitivity to Initiation:	
Seconds, 0.1 (no cop used) 310	Minimum Detonaring Charge, gm	
5 Emplodes 290	Mercury Fulminate	
10	Leod Azide	
	Tetryl	
15 20	Ballistic Morter, % TNT:	_
	Treuzi Test, % Hg(ONC) ₂ (c) 88	_
75°C International Heat Test: % Loss in 48 Hrs	Plate Deat Test: Method	
100°C Heat Test:	Condition	
% Loss, 1st 48 Hrs	Confined	
% Loss, 2nd 48 Hrs	Density, gm/cc	
Explosion in 100 Hrs	Brisance, % TNT	_
Flammability Index:	Detenation Rate: Confinement	
	Condition	
Hygrescepicity: % (b) 25°C, 100% RH 0.04	Charge Diameter, in.	
2	Density, gm/cc	
Voletility: 75°C, 24 hrs 0.00	Rate, meters/second	

Silver Azide

Fragmentation Test:	Shaped Charge Effectiver see, TNT == 100:		
90 mm HE, M71 Projectile, Let WG-91:	Glass Cones Steel	Cones	
Density, gm/cc	Hole Volume		
Charge Wt, Ib	Hole Depth		
Total No. of Fragments:	Color: Whit	e to gray	
For TNT	Comp.	e co gray	
For Subject HE	Principal Uses: In	itiators	
3 insh HE, M42A1 Projectile, Let KC-S:		1 412 401 2	
Density, gm/cc			
Charge Wt, Ib	İ		
Total No. of Fragments: For TNT	Method of Leeding: Presso.		
For Subject HE			
	Louding Density: gm/cc Var	iable	
Fragment Velocity: ft/sec At 9 ft At 2514 ft	Storege:		
Dennity, gm/cc			
	Method	Wet	
Plant (Relative to TPTY):	Hazard Class (Quantity-Distance)	Class 9	
Aire	Compatibility Group	M que a)	
Peak Pressure		•••	
Impulse	Exudation	None	
Energy			
Air, Confined:	Initiating Efficiency:		
impulse	Grams Required to Give Complete Initiation of TNT	(e) 0.02-0.05	
Under Weter:	Solubility in 100 gm Solvent		
Peak Pressure	at Room Temperature:		
Impulse Success	Solvent	Grams	
Energy	Water (b)	0.006	
Undergreund:	Ammonium hydroxide	Soluble	
Peak Pressure	Nitric acid Ether (b)	Decomposes 0.017	
Impulse	Eth. 1 alcohol, 95%	0.006	
Energy	Acetone	0.015	
Explosive Power: (f)	Unaffected by water and CO2.	(a)	
Kilogram meters 192,000	Heat of:		
% Mercury Fulminate 1.097	Explosion, cal/gm (c, a)	452	

Silver Azide

Preparation;

MaN₃ + AgNO₃ → AgN₃ + MaNO₃

Prepare the following aqueous solutions:

- . a. 5% NaNg, sodium azide, 50 cc
 - b. 25% AgMO3, silver nitrate, 25 cc

The silver nitrate solution is placed in a 200 cc conductive rubber beaker equipped with a hard wood stirrer operated by an air motor. The sodium axide solution is placed in a separatory funnel fastened in a ring stand above the beaker containing the silver nitrate. A long cord (10 ft) is restened to the stopcock of the separatory funnel so that the funnel can be expited by remote control. The silver nitrate solution is now stirred very repidly and the sodium axide is slowly run into the nitrate solution. Stirring is continued for 5 minutes. The contents of the beaker are filtered through folded filter paper and vashed free of sodium axide and silver nitrate with distilled water.

Silver aside should be stored under water in a conductive rubber container. This preparation will yield approximately 7 grams.

The preparation should be conducted under a hood and behind a barricade. The product obtained by the above procedure has a very fine particle size, almost colloidal. Very fine silver axide is safer to handle and is just as efficient and stable as the large, coarse crystalline material (Ref b). When a thin film of fine silver axide is precipitated on mercury fulminate, tetryl, etc., these substances are as efficient weight for weight as pure silver axide (Ref g). White silver axide is less affected by light than mercury or lead axide (Ref h). Long colorless crystals which explode on breaking are obtained from associum hydroxide.

Origin:

Silver azide was first prepared in 1890-1 by T. Curtius (Ber 23, 3032; Ber 24, 3344-5) by passing hydrazoic acid (EMg) into neutral silver nitrate solution. Taylor and Rinkenbach prepared pure "collodial" aggregates and showed its sensitivity depends upon its particle size (Army Ordnance 5, 824 (1925). Silver azide was found in a detonator of foreign ammunition for the first time in 1945 (Ref 1).

References:65

- (a) A. R. Hitch, "Thermal Decomposition of Certain Inorganic Trinitrides," J Am Chem Soc 40, 1195 (1918).
- (b) C. A. Taylor and Wm. H. Rinkenbach, "Silver Azide: An Initiator of Detonation," Army Ordnance, Vol 5, p. 824 (1925).
 - (c) E. De W. S. Colver, High Employives, London and New York, p. 527.
 - (d) A. Stettbacher, Spreng u. Schlesstoffe, Rascher, Zurich, p. 97 (1948).
 - (e) A. Marshall, Explosives, 2nd Ed, Vol II, p. 767, London.
 - (f) A. Stettbacher, Z ges Schiess-Sprengstoffw 10, pp. 193-214 (1915).

⁶⁹See footnote 1, page 10.

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Silver Azide

- (g) F. Blechta, Chim et Ind Special No. 921-5 (June 1933); C. A. 28, 646.
- (h) L. Wohler and W. Krupko, Berichte 46, 2047-2050 (1913).
- (1) F. G. Haverlak, <u>Emandmention of 120/45 NM HE Shell</u>, Italian (FMAN-464), PATR No. 1515, 10 April 1945.

Tetracene

Composition:	Melecular Weight: (C ₂ H ₆ N ₁₀ 0) 188
% C 12.8 NH NH H 4.3	Oxygen Belence: -60 CO % -43
M 74.4 C-NH-NH-N = N-C	Density: gm/cc At 3000 psi 1.05
o 8.5 NH 2 NH-NH-NO	Melting Point: °C Explodes 140-160
C/H Ratio 0.068	Freezing Point: *C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 7	Belling Pelat: *C
Sample Wt 20 mg Picatinny Arsenal Apparatus, in.2; (8 oz vt) 8 Sample Wt, mg	Refrective Index, non non non non non non non non non no
Friction Pendulum Test:	Vocuum Stability Test:
Steel Shoe	cc/40 Hrs, at
Fiber Shoe	90°C
Riffe Bullet Impact Test: Trials	120°C
%	135°C
Explosions	150°C
Portiols Remark	
Burned Unaffected	200 Green Bernb Send Test: Sond. om 28.0
	Sond om 28.0
Explosion Temperature: *C Seconds, 0.1 (no cop used)	Sensitivity to initiation: Minimum Detonating Charge, gm
1	Mercury Fulminate 0-40
5 160	Lead Azide
10	Tetryi
15	D. West, AA. A. M. Thirt.
20	Balliatic Marter, % TNT:
TROP late motion of Manh Trans.	Trouzi Tost, % TNT: (a) 61
75°C International Heat Test: % Loss in 48 Hrs 0.5	Plate Dent Test: Method
100°C Heat Test:	Condition
% Loss, 1st 48 Hrs 23.2	Confined
% Loss, 2nd 48 Hrs 3.4	Density, gm/cc
Explosion in 100 Hrs None	Brisance, % TNT
Flormability Index:	Petenetien Rate: Confinement
Hygrescapicity: % 30°C, 90% RH 0.77	Condition Charge Diameter, in.
Volatility:	Density, gm/cc Rate, meters/second

Gloss Cones olume spth Unes: Priming co detonators F Leeding: Closs (Quantity-Distr	Pale yellow mpositions and Pressed 1.05
F Leeding:	Pressed 1.05
View: Priming conditions detonators F Looding: Density: gm/cc 3000 psi	Pressed 1.05
detonators F Leeding: Density: gm/cc 3000 psi	Pressed 1.05
detonators F Leeding: Density: gm/cc 3000 psi	Pressed 1.05
detonators F Leeding: Density: gm/cc 3000 psi	Pressed
detonators F Leeding: Density: gm/cc 3000 psi	Pressed
F Leeding: Density: gm/cc 3000 psi	Pressed 1.05
Pensity: gm/cc 3000 psi	1.05 Wet
Pensity: gm/cc 3000 psi	1.05 Wet
Pensity: gm/cc 3000 psi	1.05 Wet
Pensity: gm/cc 3000 psi	Wet
3000 psi	Wet
3000 psi	Wet
ı	Wet
Class (Quantity-Distr	once) Class 9
tibility Group	Group M
ion	
ty:	
	4
	in water, alcohol, carbontetrachloride
ity to Electrosta	tic
	(b)
fined	0.010
ned	0.012
sion, cal/gm	658
	1190
ng Efficiency:	
cene is not effic	VIG 01118
vient in the second sec	vity to Electrosta ge, Joules: onfined ined cosion, cal/gm as Volume, cc/gm cing Efficiency: racene is not effic pplosives.

Tetracene

Preparation:

(Rinkenbach and Burton, Army Ordnance 12, 120 (1931)).

Tetracene is prepared by dissolving 5 gms of aminoguanidine dinitrate in 30 cc of water, cooling to 0°C and mixing with a solution of 2.5 gms of sodium nitrate in 15 cc of water. The temperature is maintained at about 10°C and 0.5 gm of acetic acid is added. The tetracene separates out and is washed with water, alcohol and ether. It is then dried.

Tetracene may also be prepared by placing aminoguanidine sulphate and sodium nitrite in a large beaker and adding water hered to 30°C. The heat of reaction causes the mixture to boil; after standing for two or three hours the separated tetracene is filtered off, washed thoroughly and dried.

Origin:

Tetracene was first prepared in 1910 by Hoffman and Roth (Ber 43, 682) who also studied its chemical reactions and determined its structure (Hoffman et al, Ber 43, 1087, 1866 (1910); Ber 44, 2496 (1911); and Ann 380, 131 (1911)). W. H. Rinkenbach and O. Burton made an extensive study of tetracene and described its manufacture and explosive properties (Army Ordnance 12, 120 (1931)).

Destruction by Chemical Decomposition:

Tetracene is decomposed by adding it to boiling water and continuing boiling for some time to insure complete decomposition.

References: 70

- (a) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- L. C. Smith and E. G. Eyster, Physical Testing of Explosives. Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.
 - (c) Also see the following Picatinny Arsenal Technical Reports on Tetracene:

<u>o</u>	1	<u>3</u>	<u>4</u>	7	<u>8</u>	2
1450	11	453	1104 2164	407	318	859 21 7 9

70See footnote 1, page 10.

Tetranitrocarbazole (TNC)

Composition:		Molecular Weight: (C ₁₂ H ₅ N ₅ O ₈)	347
% O ₂ N H N N N N N N N N N N N N N N N N N N	NO	Oxygen Belence: CO ₂ % CO %	-85 -30
H 1.4	No ₂	Density: gm/cc	4
и 20.0	•	Molting Point: °C Pure 1,3,6,8-is	omer 296
0 37.0 C/H Ratio 1.032		Freezing Point: *C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	100+	Beiling Point: *C	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in: Sample Wt, mg	18	Refrective Index, no no no no no no no no no no no no no	
Friction Pendulum Test:		Vecuum Stability Test:	
3.30. 3.30	Inaffected	cc/40 Hrs, at 90°C	
Fiber Shoe	Inaffected	100°C	0.2
Rifle Bullet Impact Test: Trials		120°C	0.2
% 5		135°C	
Explosions Partials		150°C	
Burned		200 Grem Bomb Sond Test:	
Unaffected		Sand, gm	41.3
Explosion Temperature: 'C		Sensitivity to Initiation:	
Secono: 0.1 (no cap used)		Minimum Detonating Charge, gm Mercury Fulminate	
D. composes 470		Lead Azide	0.20
10		Tetryl	0.25
15			
20		Bellistic Morter, % TNT:	
75°C International Heat Test:		Trouxi Test, % TNT:	
% Loss in 48 Hrs		Plate Dent Test: Method	
190°C Heat Test:		Condition	
% Loss, 1st 48 Hrs	0.15	Confined	
% Loss, 2nd 48 Hrs	0.05	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
Commobility Index:		Detenation Rate: Confinement	•
Hygreecepicity: % 30°C, 90% RH	0.01	Condition Charge Diameter, in.	
		Density, gm/cc	

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Tetranitrocarbazole (TNC)

Fragmentation Test:	Shaped Charge Effectiveness, TNT = '	TNT = 100:	
90 mm HE, M71 Projectile, Let WC-91:	Gicss Cones Steel	Cones	
Density, gm/cc	Hole Volume		
Charge Wt, Ib	Hole Depth		
Total No. of Fragments:	Color: Ld	ight yellow	
For TNT	, Cam.	Ruc Aerroa	
For Subject HE	Principal Uses: Component of ign	iter and	
3 inch HE, M42A1 Projectile, Let KC-5:	pyrotechnic com	positions	
Density, gm/cc			
Charge Wt, Ib			
Total No. of Fragments:	Method of Leeding:	Pressed	
For TNT	mesical or covering:	Liesed	
For Subject HE			
	Leeding Density: gm/cc		
Fragment Valuelty: ft/sec At 9 ft	•		
At 251/4 ft	Storage:		
Density, gm/cc			
	Method	Dry	
Staat (Relative to TNT):	Hazard Class (Quantity-Distance)	Class 9	
Air:	Compatibility Group		
Peak Pressure	•		
Impulse	Exudation		
Energy			
Air, Confined:	Solubility in Water,		
Impulse	gm/100 gm (%), at:		
	95°C	0.10	
Under Weter:	/ //	0.20	
Peak Pressure	Qualitative Solubilities:		
Impulse	Solvent	Solubility	
Energy			
	Ni trobenzene	Very soluble	
Underground:	Acetone Benzene	Soluble Insoluble	
Peak Pressure	Chloroform	Insoluble	
Impulse	Carbontetrachloride	Insoluble	
Energy	Ether	Insoluble	
	Ether, petroleum	Insoluble	

Tetranitrocarbasole (TNC)

Preparation:

Sulfonation: Fifty-six gms of carbazole is dissolved in 320 gms of H₂SO_L (96%, specific gravity 1.84). The solution is agitated during the addition of the carbazole and the temperature maintained at 25°-35°C. After the addition of the carbazole is completed, the agitation is continued and solution completed by raising the temperature to 80°-85°C and maintaining this temperature for one hour. The sulphate is now cooled to 20°C.

Mitration: The sulfonate solution is slowly added to 168 gms of HNO₃ (Plant grade specific gravity 1.525 at 15°C) saintaining the temperature at 30° to 50°C. (Time required - 1 hour 25 minutes). The temperature is then gradually raised to 70° to 75°C and maintained for one hour after which the temperature is raised to 85° to 90°C and held for one hour, then lowered to room temperature before drowning.

Drowning: The nitration mixture is drowned by pouring it into 2 to 3 volumes of ice and

Filtering: The separated light yellow product is filtered on a Buchner Funnel and washed with water twice to remove most of the acid.

<u>Purification:</u> The TMC is placed in hot water (95° to 100° c) and boiled for five to ten minutes with rapid agitation, allowed to settle then filtered and washed once. This procedure is repeated twice, making a total of three "boilings." The final wash is acid free.

Drying: The TNC is spread in a thin layer and dried at 100° to 110°C for four hours.

Yield: 73.3%.

Melting Point of TNC as prepared: 280°C (compares to 296°C for pure 1,3,6,8-isomer in preceding data).

Origin:

The preparation of Tetranitrocarbazole (TNC) was first reported in 1880 by C. Graebe (Ann 202, 26 (1880)) who nitrated carbazole with 94% nitric acid. Similar procedures were followed by R. Escales (Ber 37, 3596 (1904)) and P. Zierch (Ber 42, 3800 1909)). However, G. L. Clamician and P. P. Silber observed the formation of four isomeric TNC's when acetyl carbazole was treated with fuming nitric acid (Gazz chim ital 12, 272 1882). In 1912 and 1913 patents were issued to the dyestuff manufacturer, Casella and Company, covering the preparation of polynitrocarbazoles (German Patent 268,173 and French Patent 464,536). The Casella process of

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Tetranitrocarbazole (TNC)

preparing polynitrocarbazoles by dissolving carbazole in sulfuric acid and treating the solution of sulfonic acids with strong nitrating agents is essentially the process used today in the United States. The crude product, thus prepared, contains principally 1,3,6,8-TNC (W. Borsche and B. G. B. Scholten Ber 50, 596 (1917) and about 10% of the 1,2,6,8-TNC isomer (D. B. Murphy et al J Am Chem Soc 75, 4289 (1953). TNC was used in explosives by the Germans during World War II.

References: 71

- (a) D. B. Murphy, F. R. Schwartz, J. P. Picard and J. V. R. Kaufman, "Identification of Isomers Formed in the Nitration of Carbszole," J Am Chem Soc, 75, 4289-4291 (1953).
- (b) S. Livingston, Preparation of Tetranitrocarbazole, PA Chemical Research Laboratory Report No. 136, 330, 11 April 1951.
- (c) D. B. Murphy et al, Long Range Basic Technical R.search Leading to the Development of Improved Ignition Type Powders The Chemistry of Tetranitrocarbazole, PA Memorandum Report No. 22, 2 September 1952.
 - (d) S. Livingston, Development of Improved Ignition Type Powders, PATR No. 2267, July 1956.
 - (e) Also see the following Ficatinny Arsenal Technical Reports on Tetranitrocarbazole:

0 2 3 4 7 2180 1802 1973 1984 1647 1937

⁷¹See footnote 1, page 10.

2,4,2',4'-Tetranitro-oxanilide (TNO)

Composition:	Molecular Weight: (C14H8N6O10) 420	
% ° 40.0 ° .	Oxygen Belonce:	
Ī) CO ₂ % -84	
H 1.9 NH 人 WO	NH CO % -31	
N 20.0	NO ₂ Density: gm/cc	
0 38.1	Melting Point: °C Decomposes 313	
C/H Ratio 0.735	NC ₂ Freezing Point: *C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	Boiling Point: °C	
Sample Wt 20 mg	Refrective Index, no	
Picatinny Arsenal Apparatus, in. 30 Sample Wt, mg 11	,	
and the straining and the stra	n _{so}	
Friction Fondulum Test:	Vocuum Stubility Test:	
Steel Shoe Unaffect		
Fiber Shoe Unaffed		
810- 8-M-4 1 7 7	100°C	
Rifle Bullet Impact Test: Trials	120°C 0-11	
% Explosions	135°C	
Partials	150°C	
Burned	200 Grum Bomb Sand Test:	
Unaffected	Sand, gm 16.3	
Explosion Temperature: °C	Sensitivity to Initiation:	
Seconds, 0.1 (no cop used)	Minimum Detonating Charge, gm	
	Mercury Fulminate	
5 392	Lead Azide 0.20	
10 15	Tetryl 0.25	
20	Bellistic Morter, % TNT:	
	Treuzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plete Dent Test: Method	
100°C Heat Test:	Condition	
	.07 Confined	
·	.00 Density, gm/cc	
	one Brisance, % TNT	
Explosion in rootins Inc		
Flammability Index:	Detonation Rate: Confinement	
·	Condition	
Hygrescopicity: % 30°C, 90% RH Tr	Charge Diometer, in.	
	Density, gin/cc	
Veletility:	a control to the control of the cont	

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2,4,2',4'-Tetranitro-omanilide (TNO)

Fregmentation Test:	Shaped Charge Effectiveness, TNT = 100:		
90 man HE, M71 Projectile, Let WC-91; Eunsity, gm/cc Charge Wt, ib	Glass Cones Stept Cones Hole Volume Hole Depth		
Total No. of Fragments: For TNT	Color: Light yellow		
For Subject HE 3 Inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib	Principel Uses: Component of black powder type and pyrotechnic compositions		
Total No. of Fragments: For TN I' For Sub, act HE	Method of Loading: Pressed and extruded compositions		
Fragment Velocity: ft/sec	Leading Density: gm/cc		
At 9 ft At 25½ ft Density, gm/cc	Sterege:		
Bleet (Relative to TNT):	Method Dry Hazard Class (Quantity-Distance) Class 9		
Air: Peck Prassure Impulse Energy	Compatibility Group Exudation		
Air, Confined: Impulse	Solubility, gm/100 cc Solvent, in:		
Under Weter: Peok Pressure Impulse	Water 100 <0.10 Nitrobenzene 150 >15 Qualitative Solubilities:		
Energy Underground: Peoix Pressure Impulse Energy	Solvent Ethyl alcohol Benzene Butyl acetate Carbontetrachloride Ethyl ether Acetic acid Nitric acid Soluble Soluble Soluble Soluble		

Method of Preparation:

Omanilide:

Two parts of oxalic acid are mixed with one part of aniline in a round bottom flask. The mixture is stirred and heated until the reaction is complete as evidenced by the cessation of effervescence. The mass is cooled to room temperature, poured into several volumes of water (21°-24°C), filtered on a Büchner funnel and washed free of oxalic acid with water and then washed free of aniline with acetone. The oxanilide is air dried to remove the acetone and then dried at 100°-110°C.

Tetranitro-oxanilide (TNO):

A 5 liter round bottom flask is equipped with a stirrer of a type which wil? produce a accuracy "swirl." The flask is surrounded with a water jacket for hot and cold water. Fifteen hundred grams (1.5 kilograms) of 98% plant grade nitric acid is placed into the flask. Five hundred (500) grams of ommilide is slowly added to the acid under rapid agitation while the temperature is maintained below 10°C. After the addition of the ommilide is completed (2½-3 hrs), the agitation is continued 10-15 minutes. The temperature is then raised to 80°C over a period of one hour and maintained at 80°-85°C for 3 hours. The acid slurry is then cooled to room temperature and drowned by pouring over cracked ide. The product is filtered on a Büchner funnel and washed with water until it is almost acid free. The filter cake is placed in a beaker and sufficient water added to form a "slurry." Live steam is run into the "slurry" under agitation for 10 minutes. The slurry is filtered and the residue washed. The latter treatment of the "slurry" is repeated until the wash water is found to be neutral to

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2,4,2',4'-Tetranitro-oxanilide (TNO)

litmus paper. The TNO is washed with alcohol, then acetone, air dried and finally dried at 100° - 100° C.

Yield = 90% to 97.5% of theoretical.

Origin:

A. G. Perkin in 1892 obtained tetranitro-oxanilide directly by heating a solution of finely powdered oxanilide in nitric acid. He also obtained the same compound by the action of a cooled mixture of nitric and sulfuric acids on oxanilide and precipitating the product by pouring the solution into water (J Chem Soc 61, 460 (1892).

References: 72

- (a) S. Livingston, Development of Improved Ignition Type Powders, PATR No. 2267, July 1956.
- (b) D. Dubrow and J. Kristal, Substitution of Tetranitro Oxanilide and Hexanitro Oxanilide for Tetranitro Carbazole, PA Pyrotechnic Pessarch Laboratory Report 54-TF 1-88, 20 December 1954.

⁷²See footnote 1, page 10.

Tetryl

Composition:		Molecular Weight: (C7H5N508)	287
C 29.3 H ₃ C-	N-NO ₂	Oxygen Belence: CO ₂ % CO %	-147 - 8
и 24.4	3	Density: gm/cc Crysta	1 1.73
0 44.6	Y	Melting Point: *C	130
C/H Ratio 0.420	NO ₂	Freezing Point: *C	·
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	26	Boiling Point: *C	
Sample Wt 20 mg Picotinny Arsenal Apparatus, in. Sample Wt, mg	8 18	Refrective Index, no no no no no no no no no no no no no	
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe	Crackles	cc/40 Hrt. at	
Fiber Shoe	Unaffected	90°C	••
		100°C	0.3
Rifle Bullet Impact Test: Tric!s		120°C	1.0
% 5		135°C	••
Explosions 13		150°C	11+
Partials 5 ¹ 4			
Burned 10		200 Grem Bomb Send Test:	_
Unoffected 23		Sand, gm	54.2
Explosion Temperature: °C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used) 344	0	Minimum Detonating Charge, gr	n
1		Mercury Fulminate	0.20*
5 Ignites 25		Lead Azide	0.10*
10 23		Tetwo	
15 23		1	
20 23	4	Beilistic Morter, % TNT: (a)	130
75°C International Heat Test:		Trev.zi Test, % TNT: (b)	125
% Loss in 48 Hrs	0.01	Plate Deat Test: (c)	
		Method A	В
1001G Heat Test:		Condition Pressed	Pressed
% Loss, 1st 48 Hrs	0.1	Confined Yes	No
% Lass, 2nd 48 Hrs	0.0	Density, gm/cc 1.50	1.59 1.36
Explosion in 100 Hrs	None	Brisance, % TNT 116	115 96
Flammability Index:	544	Detenation Rate: Confinement	None
Hygroscopicity: % 20°C, 90% RH	0.04	Condition	Pressed
	0.04	Charge Diameter, in.	1.0
Volatility: 25°C	0.00	Density, gm/cc	1.71
	0.00	Rate, meters/second	7850

Reaster Sensitivity Test: Condition	(d) Pressed	Decemposition Equation: Oxygen, atoms/sec	(g) 1015.4 (h) 1012.9
Tetryl, gm	100	(Z/sec)	38.4 34.9
Wax, in. for 50% Detonation	2.01	Heat, kilocalorie/mole (ΔΗ, kcal/mol)	JU14 J419
Wax, gm		Temperature Range, °C	211-260 132-164
Density, gm/cc	1.58	Phase	Liquid Liquid
Heat of:		Armer Plate Impact Test:	
Combustion, cal/gm	2925		
Explosion, cal/gm	1080-1130	60 mm Mortor Projectile:	
Gas Volume, cz/gm	760	50% Inert, Velocity, ft/	sec
Formation, cal/gm	-14	Aluminum Fineness	
Fusion, cal/gm o (e) Temperature, o	22.2 127	500-lb General Purpose Be	mbe:
Specific Heat: cal/gm/*C	(e)		
-1 00	0.182	Plate Thickness, inches	
- 50	0.200	1	
0	0.212	194	
50 100	0.223 0.236	11/2	
100	0.230	13/4	
Burning Rate: cm/sec		-	
Thermal Conductivity: (f) col/sec/cm/*C 5.81 x 10_1, at 6.83 x 10 at	1.394 gm/cc	T7, 2000-lb Semi-Armer-Pi	iorcing Bomb vs Concreto:
	1.)20 gm/ ee	Max Safe Drop, ft	
Coefficient of Expension: Linear, %/°C		500-lb General Purposs de	omb vs Concrete:
Volume, %/°C		Height, ft	
Mandage Mahal Roste		Trials	
Herdness, Mohs' Scale:		Unaffected	
Young's Modulus:		Low Order	
E', dynes/cm²		High Order	
E, lb/inch²		1000-lb General Purpose B	omb vs Concrete:
Density, gm/cc			
Companying Strength, Ib /ingl-7		Height, ft	
Compressive Strength: Ib/inch ²		Trials	
		Unaffectea	
Vapor Pressure:		Low Order	
°C mm Mercury		High Order	

61 .					
.91 :		Glass Con	es Steel (Cones	
1.58	Hole Volu	me			
2.052	Hole Depti	h			
	Colon		71-		
703	Color:		rrg	ur Aerron	•
864	Principal Uni	Booster	er ingred	lent of e	
. -5 :		sive mi	ixtures, d		
1.62		plasti	ig caps		
0.848					
	Method of 1	adlas.			
514		reason.		Free	seu
605	1 - 1				
	Looding Deni	My: gm/cc	See to	elow	
	Storage:				
	Method			Dr"	
	Hazard Cl	oss (Quantity-	Distance)	Clas	s 9
	Compatibil	ity Group		Grou	ıp L
	Exception		Does not	evide at	65 ³ C
			Does not	exude a	. 0, 0
	Loading Den	sity: gm/c	ee		
				x 10 ³	
			10 12	15	20
	0.9 1.40	1.47 1	57 1.60	1.63	
	İ		30		
		1			
	Effect of T	emperature	on	(3)	
			-54	2	L
	Density,	gm/cc			
	Rate, m/	8€ C	7150	71	70
	J				
	2.052 703 864 -5: 1.62 0.848	2.052 Hole Depth 703 864 Principal Use 2.5: 1.62 0.848 Method of Le Storage: Method Hazard Cli Compatibil Exudation Loading Den Cast 1. 0 3 0.9 1.40 Effect of T Rate of Det 16 hrs a Density,	2.052 Hole Depth Color: 703 864 Frincipal Uses: Booster sive missive Color: Color: Color: Color: Itiginal Uses: Boosters; ingred sive mixtures, de blasting caps 1.62 0.848 Method of Loading: Loading Density: gm/cc See be Storage: Method Hazard Class (Quantity-Distance) Compatibility Group Exudation Does not Loading Density: gm/cc Cast 1.62 Pressed psi : 0 3 5 10 12 0.9 1.40 1.47 1.57 1.66 30 1.71 Effect of Temperature on Rate of Detonation: 16 hrs at, 0 -54 Density, gm/cc 1.55	Color: Light yellow 864 Frincipal Uses: Boosters; ingredient of esive mixtures, detonstors blasting caps 1.62 0.848 Method of Leading: Pres Leading Density: gm/cc See below Sterage: Mathod Dr. Hazard Class (Quantity-Distance) Class Compatibility Group Group Exudation Does not exude at Loading Density: gm/cc Cast 1.62 Pressed psi x 10 ³ 0 3 5 10 12 15 0.9 1.40 1.47 1.57 1.60 1.63 30 1.71 Effect of Temperature on (1) Rate of Detonst.on: 16 hrs at, Oc -54 2 Density, gm/cc 1.52 1.	

Preparation:

(Manufacture of Tetryl by Dinitromonomethylaniline Process, Wannamaker Chemical Cc., Inc.)

$$c_{6}H_{3}(No_{2})_{2}c_{1} + c_{1}H_{2}H_{2} + NaOH \longrightarrow c_{6}H_{3}(No_{2})_{2}-NH-CH_{3} + NaCl + H_{2}O$$
 $c_{6}H_{3}(No_{2})_{2}-NH-CH_{3} + 2HNO_{3}$
 $o_{2}N$
 $H_{3}C-N-NO_{2}$
 $No_{2}N$
 $H_{2}C-N-NO_{2}$
 $No_{2}N$

To a solution of 202.5 gm dinitrochlorbenzene in 200 cc benzene, at 75°C with good sgitation, in 15 to 20 minutes, add 112 gm of 30% aqueous monomethylamine. Then add 129 gm of 31% aqueous sodium hydroxide, in 15 to 20 minutes, at such a rate as to cause refluxing; continue agitation for 3 hours at 70°C. The mixture is concentrated to a liquid temperature of 101°-102°C, cooled, filtered and the precipitate washed with distilled water until the washings give no test with silver nitrate, dried at 60°C (melting point 167.2°C)

The dinitromethylaniline is nitrated to tetryl by solution of it in 88% sulfuric acid (197 gm nitroaniline/1190 gm sulfuric) at 25°C, followed by addition of nitric acid. The process is carried out so that the water content remains at 16%. Solution (per 197 gm nitroaniline) requires 5 to 10 minutes, nitration, by addition of the sulfuric acid solution to nitric acid, about 1 hour at 30°C, plus 48 minutes at 50° to 55°C at the end. The mixture is then cooled to 20°C and filtered. The tetryl is dumped into 1 liter water, washed 2 or 3 times with 200 cc cold water, and then stirred 10 to 15 minutes at 50°C with 500 cc water, filtered warm and then washed with water until the washings are neutral to methyl orange. The tetryl dried to constant weight at 70°C weighs about 270 gm.

Tetryl filtered from an acid containing 87% sulfuric acid (or more) -13% water, at 40°C (or over) may fire in 30 minutes to 1 hour and 30 minutes, if not drowned in water. A safe nitration procedure, even on plant scale involves:

- 1. The concentration of sulfuric in the spent acid is maintained at a low level (approx 80/1.5/18.2 sulfuric/nitric/water).
 - 2. Nitration maximum temperature is 50°C.
 - 3. The slurry is cooled to $35^{\circ}\mathrm{C}$ before filtration.
 - 4. Filtration time prior to drowning, is minimized (15 minutes maximum).

The crude tetryl produced is recrystallized to remove impurit γ and occluded acid and to control its granulation.

Tetryl

Sensitivity of tetryl electrostatic discharge, joules; through 100 mesh: (i)

Unconfined	0.007
Confined	4.4

Solubility of tetryl, grams in 100 grams (%) of:

<u>Ma</u>	ter	Carb	on tetrachl	ori de	Eth	ie".	95%	Alcehol
°c	<u>\$</u>	°c		<u> 15</u>	<u>°с</u>	2	<u>ос</u>	2
0 20 40 30 100	0.0050 0.0075 0.0110 0.0810 0.184	6 20 40 60		0.007 0.015 0.058 0.154	0 10 20 30	0.188 0.330 0.418 0.493	0 10 20 30 50	0.320 0.425 0.563 0.76 1.72 5.33
<u>Chl</u>	oroforu L	Carbon d	isulfide £	Ethyle °C	ene dichloride	<u> </u>	Acetone C	2

0 20 40 60	0.28 0.39 1.20 2.65	0 10 20 30	0.009 0.015 0.021 0.030	25 75	4.5 45	30 40 50	75 95 116 1 3 8
Trichloro	thylene	Ethyl	ace to te	Ber	zene	Polu	ene
<u>°c</u>	2	°c	2	<u>oc</u>	2	<u>°c</u>	<u> </u>
0 20 40 60 80 86	0.07 0.12 0.26 0.67 1.50 1.76	20	~ 40	20 30 40 50	7.8 10.0 12.5 16.0	20	8.5

<u>∆</u> `.	rene	71	A.T.
<u>°c</u>	<u> </u>	°c	4
20	3-3	80	ძ2
30	4.4	100	149
30 40	5.4	120	149 645
50	6.0		

Origin:

Tetryl was first described in 1879 by Michler and Meyer (Ber 12, 1792), van Romburgh and Martens studied its properties and proved its structure (Rec trav chim 2, 108 (1883); 6, 215 (1887); and Ber 19, 2126 (1886)). Tetryl was not used as an explosive until World War I.

Destruction by Chemical Decomposition:

Tetryl is decomposed by dissolving in 12 times its weight of a solution prepared from 1 part by weight of sodium sulfite (Na₂SO₃·7H₂O) in 4 parts water. The sulfite solution may be heated to 80° C to facilitate decomposition of the Tetryl.

References: 73

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- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303; 15 June 1949.
- (e) C. A. Taylor and Wm. H. Rinkenbach, "The Solubility of Trinitro-Phenylmethyl-Nitramine (Tetryl) in Organic Solvents," J Am Chem Sic 45, (1923) p. 104.
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- (i) J. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.
- (j) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.
 - (k) Also see the following Picatinny Arsem 1 Technical Reports on Tetryl:

0	1	<u>.5</u>	3	4	5	<u>6</u>	7	<u>.</u>	9
30 600 770 810 1180 1290 1360 1400 1450 1500 1510	11 361 381 621 861 1041 1131 1261 1311 1431 1471 1611	132 582 832 882 1192 1352 1372 1402 1452 1592	453 493 623 863 1113 1373 2053 2163 2233	84 1294 1784 1784 1136 1264 1264 2004	65 195 1425 525 565 635 925 1145 1285 1405 1589 1935 2105	266 556 786 986 1086 1316 1376 1446 1466 1556 1636	117 197 637 707 807 837 1047 11437 1287 1337 1367 1437 1737 1737 1737	28 438 628 708 788 838 1418 1769 1828 1838	129 179 319 609 709 849 969 1029 1209 1429 1489 1819 1969
					2125				

3see footnote 1, page 10.

Tetry to1, 80/20

Oxygen Belonce: CO2 % CO % Density: gm/cc Cast Melting Point: "C Freezing Point: "C SoiHog Feint: "C	-52 -11 1.51 68
CO % Density: gm/cc Cast Melting Point: *C Freezing Point: *C	-11
Density: gm/cc Cast Melting Point: "C Freezing Point: "C	1.51
Melting Point: "C Freezing Point: "C	
Freezing Point: *C	68
	,
BeiHag Felat: "C	
Refrective Index, no	
n _s	
n ₂₀	
Vocuum Stability Test:	
cc/40 Hrs, at	
90°C	
— 100°C	3.0
120°C	11+
135°C	
150°C	
200 Gram Bomb Sand Test:	······································
Sand, gm	54.0
Sensitivity to Init(_vien:	
Minimum Detonating Charge, gm	
Mercury Fulminate	0.22*
Leod Azide	0.17*
*Alternative initiating charges.	
Bellistic Morter, % TNT:	
Trouzi Test, % TNT:	
Plate Dent Test: Method	
Condition	
Confined	
Density, gm/cc	
Brisance, % TNT	
Outonation Rate:	
	Vecuem Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C 200 Gram Bomb Sond Test: Sand, gm Sensitivity to Init(_*len: Minimum Detonating Charge, gm Mercury Fulminate Lead Axide *Alternative initiating charges. Bellistic Morter, % TNT: Trauxi Test, % TNT: Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT

Tetrytol, 80/20

For TNT For Subject HE 3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE Leading Density: gm/cc Fragment Yelocity: tt/sec At 9 ft At 25½ ft Density, gm/cc Method Dry Hazard Class (Quantity-Distance) Class 9	regmentation Test:	Shaped Charge Effectiveners, TNT = 100:
Chorge Wt, Ib Total Na. of Frogments: For TNT For Subject HE 3 Inch HE, MAZA1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib **Vatal Na. of Frogments: For TNT For Subject HE Leading Density: gm/cc **Tregment Yelecity: ft/sec At 9 ft At 25½ ft Density, gm/cc **Method Dry Hozard Class (Quantity-Distance) Ale: Peack Pressure Impulse Energy Alir, Confined: Impulse Energy Under Water: Peack Pressure Impulse Energy Undergreend: Peack Pressure Impulse Energy Undergreend: Peack Pressure Impulse Energy Undergreend: Peack Pressure Impulse Energy Undergreend: Peack Pressure Impulse Energy Undergreend: Peack Pressure Impulse Energy Undergreend: Peack Pressure Impulse Impulse Energy	90 mm HE, M71 Projectile, Let WC-91:	Glass Cones Steel Cones
Total Na. of Frogments: For TNT For Subject HE 3 Inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, lb Tutel Na. of Frogments: For TNT For Subject HE Loading Density; gm/cc A1 9 ft A1 25/y ft Density, gm/cc Method Dry Blast (Relative to TNT): Air: Peack Pressure Impulse Energy AIr, Confined: Impulse Under Water: Peack Pressure Impulse Energy Underground: Peack Pressure Impulse Energy Underground: Peack Pressure Impulse Energy Underground: Peack Pressure Impulse Energy Underground: Peack Pressure Impulse Energy Underground: Peack Pressure Impulse Energy Underground: Peack Pressure Impulse Impulse	Density, gm/cc	Hole Volume
For TNT For Subject HE 3 lach HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, ib **Valuel No. of Fragments: For TNT For Subject HE Leading Density: gm/cc **Fragment Velocity: tr/sec At 9 ft At 25½ ft Density, gm/cc Method Dry Hazard Class (Quantity-Distance) Air: Peak Pressure Impulse Energy Air, Coeffined: Impulse Under Water: Pack Pressure Impulse Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Impulse Energy	Charge Wt, Ib	Hole Depth
For TNT For Subject HE 3 lack HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, lb Tatel No. of Fragments: For TNT For Subject HE Looding Density: gm/cc Fragment Yelecity: tt/sec At 9 ft At 25½ ft Density, gm/cc Method Dry Blast (Relative to TNT): Air: Pack Pressure Impulse Energy Air, Confined: Impulse Energy Underground: Pack Pressure Impulse Energy Underground: Pack Pressure Impulse Energy Underground: Pack Pressure Impulse Energy Underground: Pack Pressure Impulse Energy Underground: Pack Pressure Impulse Energy	<u>-</u>	Color: Light yellow to buff
3 leach HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, ib Total No. of Fragments: For TNT For Subject HE Leading Density: gm/cc Fragment Yelecity: tt/sec An 9 ft At 25½ ft Density, gm/cc Bleat (Reletive to TNT): Alar: Peak Pressure Impulse Energy Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Impulse Energy Underground: Peak Pressure Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse		
Density, gm/cc Charge Wt, Ib Total No. of Fregments: For TNT For Subject HE Loading Density: gm/cc Fregment Yelecity: ft/sec At 9 ft At 25½ ft Density, gm/cc Method Dry Blast (Relative to TNT): Hoxard Class (Quantity-Distance) Class 9 Compatibility Group Group I Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	For Subject HE	Principal Uses: Bursters, demolition blocks
Charge Wt, ib Tatel No. of Progments: For TNT For Subject HE Leading Density: gm/cc Fregment Yelecity: tt/sec At 9 ft At 25½ ft Density, gm/cc Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Woter: Peak Pressure Impulse Energy Under Woter: Peak Pressure Impulse Impulse Energy Under Woter: Peak Pressure Impulse	3 inch HE, M42A1 Projectile, Let KC-5:	
Total Ma. of Fragments: For TNT For Subject HE Loading Density: gm/cc Fragment Yelecity: tt/sec At 9 fr At 25½ ft Density, gm/cc Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Under Water: Peak Pressure Impulse Energy Under Water: Peak Pressure Impulse	Density, gm/cc	
For TNT For Subject HE Leeding Density: gm/cc Fregment Yelecity: tt/sec At 9 ft At 25½ ft Density, gm/cc Method Dry Hazard Class (Quantity-Distance) Class 9 Air: Peak Pressure Impulse Energy Air, Centined: Impulse Under Woter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Impulse Energy Underground: Peak Pressure Impulse Impulse Energy	Charge Wt, Ib	·
For Subject HE Leading Density: gm/cc Fregment Yelecity: ft/sec At 9 ft At 25½ ft Density, gm/cc Method Dry Blast (Relative to TNT): Hazard Class (Quantity-Distance) Class 9 Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse	. =	Method of Looding:
Fregment Yelecity: tt/sec At 9 ft At 25½ ft Density, gm/cc Method Dry Method Dry Method Dry Method Dry Air: Peak Pressure Impulse Energy Air, Cenfined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse		
At 25½ ft Density, gm/cc Method Dry Bleet (Relative to TNT): Atr: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Underground: Impulse Underground: Impulse Impulse Underground: Peak Pressure Impulse		Looding Density: gm/cc
Density, gm/cc Method Dry Blest (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Impulse Underground: Impulse Im	At 9 ft	•
Method Dry Blest (Reletive to TNT): Hazard Class (Quantity-Distance) Class 9 Air: Compatibility Group Group I Exudation Exudes at 65°C Air, Confined: Exudation Exudes at 65°C Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Impulse		Storage:
Ale: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Density, gm/cc	Method Dry
Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Exudation Exudes at 65°C Exudation Exudes at 65°C Under Water: Peak Pressure Impulse Energy	lest (Relative to TNY):	Hazard Class (Quantity-Distance) Class 9
Impulse Exudation Exudes at 65°C Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse		Compatibility Group Group I
Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse		Sundation Provides at 6500
Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse	•	Exaction Success to 05 C
Peak Pressure Impulse Energy Underground: Peak Pressure Impulse		
Energy Underground: Peak Pressure Impulse		
Underground: Peak Pressure Impulse	Impulse	Ì
Peak Pressure Impulse	Energy	
· ·		
Energy	Impulse	
	Energy	
	•	

Te :rytol, 75/25

Comporition: %		Molecular Weight:	270
Tetryl	75	Oxygen Belence:	
70 0 i j	12	CO ₂ % CO %	-54
INT	2 5	CO %	-12
		Density: gm/cc Cast	1.59
		Melting Point: °C	68
C/H Ratio		Freezing Point: "C	
mpest Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm Sample Wt 20 mg	28	Refrective Index, no	
Picatinny Arsenal Apparatus, in.	10	1	
Sample Wt, mg	17	กต	
		n	
riction Pendulum Test:		Vocuum Stability Test:	
Steel Shoe C	racks	cc/40 Hrs, at	
Fiber Shoe U	naffected	90°C	
Mile Bullet Impact Tests		100°C	3.0
Liffe Bullet Impact Test: Trials		120°C	11+
Explosions 0		135°C	
Partials 30		150°C	
Burned 0		200 Gram Bomb Sand Test:	
Unaffected 70		Sand, am	53.7
			73.1
x; iesian Temperature: °C		Sensitivity to Initiation:	
Ecronds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
i 5 Ignites 310		Mercury Fulminate	0.23*
10		Lead Azide	0.19*
15		*Alternative initiating charges	
20		Bellistic Morter, % TNT: (a)	122
		Transit Test, % TNT:	
5°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test: (b)	
		Method B	В
00°C Heef Test:		Condition Cast	Cast
% Loss, 1st 48 Hrs		Confined No	Yen
% Loss, 2nd 48 Hrs		Density, gm/cc 1.66	1.62
Explosion in 100 Hrs		Brisance, % TNT 118	114
Inmobility Indon. 1933		Detonation Rate:	
lemmebility Index: Will not contin	nue to burn	Confinement	None
In an anicity of	0.03	Condition	Cast
lyyreacopicity: %	0.03	Charge Diameter, in.	1.0
feletility:		Density, gm/cc	1.60
 7.		Rate, meters/second	7 3 85

Tetrytol, 75/25

Fregmentation Test:		Shaped Charge Effectiveness, TNT =	100:
90 mm HE, M71 Projectile, Let WC-1)1:	Glass Cones Steel	Cones (d)
Density, gm/cc	1.39	Hole Volume 127	
Charge Wt, Ib	2.101	Hole Depth 120	
Total Ne. of Fragments:		Color: Light vell	
For TNT	703	Light yell	low to buff
For Subject HE	857	Principal Uses: Bursters, demoli	tion blooks
3 inch HE, M42A1 Projectile, Let KC-	5:		
Density, gm/cc	1.60		
Charge Wt, ib	0.845		
Total No. of Fragments:		Method of Looding:	Cast
For TNT	514		
For Subject HE	591	Leading Density: gm/cc	1.59
Fregment Velocity: ft/sec	·		//
At 9 ft At 251/2 ft	,	Sterege:	·······
Density, gm/cc		Method	Dry
Hest (Relative to TNT):		Hazard Class (Quantity-Distance)	Class 9
Aire	X.	Compatibility Group	Group I
Peak Pressure		Eurodosian	Exudes at 65°
Impulse		Exudation	Exudes at 05
Energy		2-	<u> </u>
Air, Confined:		Eutectic Temperature, OC:	67.5
Impulse		gr Tetryl/100 gm TNT 67.5°C	54-82
Under Weter:			•
Peak Pressure		Booster Sensitivity Test:	(c)
Impulse Engage		Condition	Cast
Energy		Tetryl, gm	100
Underground: Pook Pressure		Wax, in. for 50% Detonation Density, gm/cc	1.65 1.66
Impulse			
Energy			
			

Tetrytol, 70/30

Composition: %	Melecular Weight:	266
Tetryl 70	Oxygen Bolence:	
14 11 10	CO ₂ %	-55
TNT 30	CO %	-13
	Density: gm/cc Cast	1.60
	Melting Point: *C	68
C/H Ratio	Freezing Point: *C	•
Impact Sazsitivity, 2 Kg Wt: Bureou of Mines Apparatus cm 28	Boiling Point: *C	
Bureau of Mines Apparatus, cm 28 Sample Wt 20 mg	Refrective Index, no	
Picatinny Arsenal Apparatus, in. 11	-	
Sample Wt, mg 18	n _m	
	n ₉	
Friction Pendulum Test:	Vecuum Stability Test:	
Steel Shoe Unaffected	cc/40 Hrs, at	
Fiber Shoe Unaffected	f	
Riffe Bullet Ir:pect Test: Trials	100°C	3.2
•	120°C	11+
% Exp!psions 0	135°C	
Partials 55	150°C	
Burned 0	200 Green Board Soud Toda	
Unaffected 45	200 Grem Bomb Send Text:	53.2
	Sand, gm	
Explosion Temperature: 'C	Sensitivity to Initiation:	
Seconds, 0.1 (no cop used) 416	Minimum Detonating Charge, gm	
l 387 5 Ignites 320	Mercury Fulminate	0.23*
	Leod Azide	0.22*
	*Alternative initiating charges.	
15 289 20 275	Bellistic Merter, % TNT: (a)	120
	Trauzi Teet, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plete Dent Test: (b)	
70 LASS III 90 F113	Method	В
100°C Heet Test:	Condition	Cast
% Loss, 1st 48 Hrs 0.1	Confined	Yes
% Loss, 2nd 48 Hrs 0.1	Density, gm/cc	1.60
,	n	117
Explosion in 100 Hrs None		
Flammebility Index: Will not continue to b	Detenation Rate: Confinement	None
		Cast
Mygroscopicity: % 0.02	Charge Dispetter in	
		1.60

Tetrytol, 70/30

Fregmentation Test:		Sheped Charge Effectiveness, TNT = 1	100:
90 mm HE, M71 Projectile, Lot W	/C-91:	Glass Canes Steel	Cones
Density, gm/cc	1.60	Hole Volume	
Charge Wt, Ib	2.090	Hole Depth	
Total No. of Fragments:		Color: Light ye	llow to buff
For TNT	703	Coor: Mgnc ye	ITTOM CO CUIT
For Subject HE	840	Principel Uses: Bursters, demoli	tion blooks
3 inch HE, M42A1 Projectile, Let	KC-5:	July State of State o	OLON CIOCAL
Density, gm/cc	1.60	į –	
Charge Wt, Ib	0.842	Ì	
Total No. of Fragments:		Method of Loading:	Cast
For TNT	514		OEE 0
For Subject HE	585		
	***	Leeding Density: gm/cc	1.60
Fregment Velocity: ft/sec At 9 ft At 25½ ft		Storage:	
Density, gm/cc			
		Method	Dry
Blast (Relative to TNT):		Hazard Class (Quentity-Listance)	Class 9
Air: Peak Pressure		Compatibility Group	Group I
Impulse		Exudation Exu	des at 65°c
Energy			
Air, Confined:			
Under Weter: Peak Pressure			
Impulse			
Energy			
Underground: Peak Pressure			
Impulse			
Energy			

Tetrytol, 65/35

Composition:	Molecular Weight:	264
% Tetryl 65	Oxygen Belence:	-/
	CO: % CO %	-56 -14
TNT 35	Density: gm/cc	1.60
	Melting Point: °C	68
C/H Ratio	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:	Boiling Point: °C	
Bureau of Mines Apparatus, cm 28	Refrective Index, no	
Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 11		
Sample Wt, mg 17	n ₂	
	n ₂₀	
Friction Pendulum Test:	Vecuum Stability Test:	
Steel Shoe Cracks	cc/40 Hrs, at	
Fiber Shoe Unaffected	•	• 0
Rifle Bullet Impact Test: Trials	100°C	2.8
%	120°C	11+
Explosions 0	135°C	
Partials 10	150°C	
Burned 0	200 Grem Bomb Sand Test:	
Unaffected 90	Sand, gm	52.6
Explosion Temperature: "C	Sensitivity to Initiation:	-
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, gm	
	Mercury Fulminate	0.23*
5 Ignites 325	Lead Azide	0.23*
10	*Alternative initiating charges.	
15 20	Sellistic Morter, % TNT:	
	Trauzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	-
	Condition	
100°C Heat Test:	Confined	
% Loss, 1st 48 Hrs	Density, gm/cc	
% Loss, 2nd 48 Hrs	Brisance, % TNT	
Explosion in 100 Hrs		
Flammability Index: Will not continue to b	urn Confinement	Hone
will not continue to b	Condition	Cast
Hygrescopicity: % 0.02		1.0
	Density gm/cc	1.60

Tetrytol, 65/35

Fregmentation Test:		Shaped Charge Effectiveness, TNT = 100) :
90 mm HE, M71 Projectile, Let WC-9	1:	(d) (e) Glass Cones Steel Co	nes
Density, gm/cc	1.61	Hole Volume 133 126	
Charge Wt, Ib	5.010	Hole Depth 120 119	
Total No. of Fragments:		Color:	
For TNT	703	Light yellow t	o buff
For Subject HE	856	Principal Uses: Bursters, demolitic	
3 inch HE, M42A1 Projectile, Let KC-	5:	Bursters, demoiling	DIOCER
Density, gm/cc	1.60		
Charge Wt, Ib	0.845		
Total No. of Fragments:		Method of Loading:	Cp -+:
For TNT	514		
For Subject HE	585	Assilve Design	1.60
Fregment Velocity: ft/sec		Leading Density: gm/cc	1.60
At 9 ft At 251/2 ft		Storage:	
Density, gm/cc		•	
30.2, 3 , 30		Method	Dry
Blast (Relative to TNT):		Hazard Class (Quantity-Distance)	Class 9
Air:		Compatibility Group	Group I
Peak Pressure			s at 65°c
Impulse		Exudation Exude	8 et 65 C
Energy			
Air, Confined: Impulse			
Under Weter: Peak Pressure			
Impulse			
Energy			
Underground: Peok Pressure			
Impulse			
Energy			
		1	

Compatibility with Metals:

<u>Dry:</u> Copper, brass, aluminum, magnesium, stainless steel, mild steel mild steel coated with acid proof black paint and mild steel plated with copper, cadmium, zinc or nickel are unaffected. Magnesium-aluminum alloy is slightly affected.

Wet: Stainless steel and mild steel coated with scid-proof black paint are unaffected. Copper, brass, aluminum, magnesium, magnesium-aluminum alloy, mild steel and mild steel plated with cadmium, copper, zinc or nickel are slightly affected.

Preparation:

Tetrytols are manufactured by heating TNT in a melting kettle, equipped with a stirrer, until all the TNT is melted. The necessary amount of tetryl is added and heating and stirring are continued. The temperature is allowed to drop from 100°C until the mixture is of maximum viscosity suitable for pouring. Part of the tetryl dissolves in TNT forming a eutoctic mixture which contains 55 percent tetryl. This mixture freezes at 67.5°C.

Origin:

Tetrytols were developed during World War II. The 70/30 tetryl/TNT castable mixture is the most important in military applications.

References: 74

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Expressives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.
 - (b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 503, 11 August 1942.
- (c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (d) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W6/2-ORD-5723.
- (e) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, Eastern Lab, du Pont, 18 September 1943, NDRC Contract W-672-ORD-5,23.
 - (f) Also see the following Picatinny Arsenal Technical Reports on Tetrytol:

<u>o</u>	<u>1</u>	2	<u>3</u>	2	<u>6</u>	<u>7</u>	8	2
1260 1360 1420 1500 1530	1291 1311 1451 1651 1951	1372	1193 1213 1363 1493	1285 1325 1885 2125	1376 1436 1466 1506	1477 1737 1797	1158 1388 18 3 8	1379

⁷⁴See footnote 1, page 10.

TNT (Trinitrotoluene)

Composition:		Molecular Weight: (C	7 ^H 5 ^N 3 ^O	₆)	227
С 37.0	CH ₃	Oxygen Belence: CO ₂ % CO %			-74 -25
N 13.5	NO ₂	Density: gm/cc	Crysta	1	1.65
0 42.3		Melting Point: °C			91
C/H Ratio 0.549	NO ²	Freezing Point: "C			
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C			
Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	95-190+ 14-15 17	Refrective Index, no		a B T	1.5430 1.6742 1.717
Friction Pendulum Test:		Vocuum Stability Test:	· · · · · · · · · · · · · · · · · · ·		
Steel Shoe	Unaffected	cc/40 Hrs, at			
Fiber Shoe	Unaffected	90°C			0.10
Rifle Bullet Impact Test: Trials		- 100°C			0.10
%		120°C			0.44 0.23
Explosions 4		150°C			0.65
Partials 0		150 C			V. 07
Burned 0		200 Grem Bomb Sand T	est:		
Unaffected 6		Sand, gm			48.0 4
Explosion Temperature: °C Seconds, 0.1 (no cap used) 570		Sensitivity to Initiation: Minimum Detonating		, gm	o obx
1 520 5 Decomposes 475		Mercury Fulminate	•		0.24* 0.27*
10 465		Leod Azide			0.21*
15		*Alternative initi	uting	charges.	
20		Bellistic Morter, % TN	T:	St	d=100
	······································	_ Trauzi Test, % TNT:		St	d=200
75°C International Heat Test: % Loss in 48 Hrs	0.04	Plete Dent Test: Method	A	(a) A	В
100°C Heat Test:		Condition	Cast	Pi ssed	Cast
% Loss, 1st 48 Hrs	0.2	Confined	Yes	Yes	No
% Loss, 2nd 48 Hrs	0.2	Density, gm/cc	1.61	1.50	1.61
Explosion in 100 Hrs	None	Brisance, % TNT	100	100	100
		Detonation Rate:			
Flammability Index: (b)	100	Confinement	Un	confined	Unconfin
A		- Condition	Pr	essed	Cast
Hygrescepicity: % 30°C, 90% RH	0.03	Charge Diameter, in			1.0
Velatility: 30°C	N4.7	Density, gm/cc	1.		1.56
v oracimy : 30 C	N11	Rate, nieters/second	68	25	66 40

TNT (Trinitrotoluene)

Booster Sensitivity Test:	(c)		Decomposition Equation:	(h) 10 ^{11.4}	10 ^{12.2}
Condition	Pressed	Cast	Oxygen, atoms/sec	10	10,22,2
Tetryl, gm	100	100	(Z/sec)	34.4	43.4
Wax, in. for 50% Det	onation 1.68	0.82	Heat, kilocalorie/mole (AH, kcal/mol)	54.4	73.4
Wax, gm			Temperature Ronge, °C	275-310	23b- 277
Density, gun/cc	1.55	1.60	Phase	Liquid	Liquid
Heat of:	(a)		_		
Combustion, cal/gm	• •	36 20	Armor Plate Impact Test:		
Explosion, cal/gm		1080	40 Marka Basicalia		
Gas Voiume, cc/am	1	730	60 mm Morter Projectile: 50% Inert, Velocity, ft	/sec	(j) ≯1100
Formation, cal/am		78.5	Aluminum Fineness	, 555	,
_		22.34	Aldinion inches		
Fusion, col/gm Temperature, OC		79	500-lb General Purpose Be	ombs:	(3)
Specific Heat: cal/gm/*(c		Plate Thickness, inches	Trials	% Inert
5 0	•	0.309	risite ittickiness, inches		W THEI C
20		0.32 8	1 .	0	
50 80		0.353	114	0	
00		0 - 374	11,2	7	100
			134	7	50
Burning Rote:			_	7	,,
cm/sec					
			9 S T		
			Bomb Drop Test:		
Thermal Conductivity:			-	Piercine Samb	va Concrete:
Thermal Conductivity: cal/sec/cm/°C	See next po	age.	Bomb Drop Test: Y7, 2000-lb Semi-Armer-I	Piercing Bomb	vs Concrete:
cal/sec/cm/°C		age.	-		vs Concrete: 00-6000
cal/sec/cm/°C Coefficient of Expansion:	(b)		T7, 2000-lb Semi-Armer-I Max Safe Drop, ft	500	00-6000
cal/sec/cm/°C Coefficient of Expansion: Linear, %/°C =40°	(b)	10 ⁻⁵ (b)	T7, 2000-lb Semi-Armer-I	500 omb vs Concre	00-6000
Coefficient of Expension: Linear, %/*C = 40° = 40°	(b) to 60°C 5.4 x to 60°C 6.7 x	10 ⁻⁵ (b)	T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B	500 omb vs Concre No Seal	00-6000 Me: Seal
Coefficient of Expension: Linear, %/*C = 40° = 40° Volume, %/*C 27°	(b) to 60°C 5.4 x to 60°C 6.7 x	10 ⁻⁵ (b)	T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft	500 omb vs Concre No Seal 4,000	00-6000 He: Seal 4-5,000
Coefficient of Expansion: Linear, %/*C =40° =40° Volume, %/*C 27° 16°	(b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x 1 to 70°C 26.3	10 ⁻⁵ (b) 10 ⁻⁵ (b)	T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials	500 omb vs Cencre No Seal 4,000 26	00-6000 Me: <u>Seal</u> 4-5,000 20
Coefficient of Expansion: Linear, %/*C =40° =40° Volume, %/*C 27° 16°	(b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x	10 ⁻⁵ (b) 10 ⁻⁵ (b) 10 ⁻⁵ (b) 10 ⁻⁵ (c)	T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected	500 500 500 500 500 500 500 500	00-6000 Ne: Seal 14-5,000 20
Coefficient of Expension: Linear, %/*C = \lambda 0^\text{-100} Volume, %/*C 270\\ 160 Hardness, Mohs' Scale:	(b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x 3 to 70°C 26.3 3	10 ⁻⁵ (b) 10 ⁻⁵ (b) 10 ⁻⁵ (b) 1.4	T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials	500 500 500 500 500 500 500 500	00-6000 Ne: Seal 4-5,000 20 20 0
cal/sec/cm/°C Coefficient of Expension: Linear, %/°C -\u00000 -\u00000 Volume, %/°C 27° 16° Herdness, Mohs' Scale: Your-' Medulus:	(b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x 3 to 70°C 26.3 3	10 ⁻⁵ (b) 10 ⁻⁵ (b) 10 ⁻⁵ (b) 1.4	T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected	500 500 500 500 500 500 500 500	00-6000 Ne: Seal 14-5,000 20
cal/sec/cm/°C Coefficient of Expension: Linear, %/°C =40° =40° Volume, %/°C 27° 16° Hardness, Mohs' Scale: Your-' Madulus: E', Jynes/cm²	(b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x 3 to 70°C 26.3 3 (e)	10 ⁻⁵ (b) 10 ⁻⁵ (b) 10 ⁻⁵ (c) x 10 ⁻⁵ (c) 1.4	T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected Low Order High Order	500 500 500 500 500 500 500 500	00-6000 Ne: Seal 4-5,000 20 20 0
cal/sec/cm/°C Coefficient of Expension: Linear, %/*C =40° =40° Volume, %/*C 27° 16° Merdness, Mohs' Scale: Your-' Wedulus: E', uynes/cm² E, lb/inch²	(b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x 3 to 70°C 26.3 3 (e)	10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) x 10 ⁻⁵ (a) 1.4	T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected Low Order	500 comb vs Cencre No Sea1 4,000 26 24 2 0	00-6000 Ne: Seal 4-5,000 20 20 0
cal/sec/cm/°C Coefficient of Expension: Linear, %/°C =40° =40° Volume, %/°C 27° 16° Herdness, Mohs' Scale: Your-' Madulus: E', Jynes/cm²	(b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x 3 to 70°C 26.3 3 (e)	10 ⁻⁵ (b) 10 ⁻⁵ (b) 10 ⁻⁵ (c) x 10 ⁻⁵ (c) 1.4	T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose I	500 comb vs Cencre No Sea1 4,000 26 24 2 0 comb vs Cencre No Sea1	00-6000 Ne: Seal 4-5,000 20 20 0 0 0 ste: Seal
cal/sec/cm/°C Coefficient of Expension: Linear, %/*C =40° =40° =40° Volume, %/*C 27° 16° Mardness, Mohs' Scale: Your-' Wedulus: E', uynes/cm² E, lb/inch² Density, gm/cc	(b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x : to 70°C 26.3 : (e)	10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) 1.4 (c) 1.4 (c) 1.4 (c)	T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose I Height, ft	500 comb vs Cener No Sea1 4,000 26 24 2 0 comb vs Cener No Sea1 5,000	00-6000 Ne: Seal 4-5,000 20 20 0 0 ste: Seal 5,000
cal/sec/cm/°C Coefficient of Expension: Linear, %/*C = 40° = 10° Volume, %/*C = 27° 16° Merdness, Mohs' Scale: Your-' Vadulus: E', uynes/cm² E, lb/inch² Density, gm/cc Compressive Strongth: lb	(b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 ; (e) (b)	10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) x 10 ⁻⁵ (a) 1.4 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161	T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose I	500 comb vs Cencre No Sea1 4,000 26 24 2 0 comb vs Cencre No Sea1	00-6000 Ne: Seal 4-5,000 20 20 0 0 she: Seal 5,000 26
cal/sec/cm/°C Coefficient of Expension: Linear, %/*C =40° =40° =40° Volume, %/*C 27° 16° Mardness, Mohs' Scale: Your-' Wedulus: E', uynes/cm² E, lb/inch² Density, gm/cc	(b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 ; (e) (b)	10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) 1.4 (c) 1.4 (c) 1.4 (c)	T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose I Height, ft	500 comb vs Cener No Sea1 4,000 26 24 2 0 comb vs Cener No Sea1 5,000	00-6000 Ne: Seal 4-5,000 20 20 0 0 ste: Seal 5,000
cal/sec/cm/°C Coefficient of Expension: Linear, %/°C -40° -40° Volume, %/°C 27° 16° Herdness, Mohe' Scale: Youn-' Madulus: E', uynes/cm² E, lb/inch² Density, gm/cc Compressive Strength: lb Density, gm/cc	(b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 ; (e) (b)	10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) x 10 ⁻⁵ (a) 1.4 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161 0-14000 1.62	T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose I Height, ft Trials	500 comb vs Concre No Sea1 4,000 26 24 2 0 clemb vs Concre No Sea1 5,000 21	00-6000 Ne: Seal 4-5,000 20 20 0 0 she: Seal 5,000 26
cal/sec/cm/°C Coefficient of Expession: Linear, %/°C =40° =40° =40° Volume, %/°C 27° 16° Herdness, Mohe' Scale: Your-' Vadulus: E', uynes/cm² E, lb/inch² Density, gm/cc Compressive Strongth: lb Density, gm/cc Vaper Pressure:	(b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x 3 to 70°C 26.3 3 (e) (b)	10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) x 10 ⁻⁵ (a) 1.4 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161	T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose B Height, ft Trials Unaffected	500 somb vs Concre No Seal 4,000 26 24 2 0 0 clomb vs Concre No Seal 5,000 21 18	00-6000 Ne: Seal 4-5,000 20 0 0 0 ste: Seal 5,000 26 22
cal/sec/cm/°C Coefficient of Expension: Linear, %/°C -40° -40° -40° Volume, %/°C 27° 16° Mardness, Mohs' Scale: Your-' Vadulus: E', uynes/cm² E, Ib/inch² Density, gm/cc Compressive Strength: Ib Density, gm/cc Vapor Pressure: °C m 80	(b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x 3 to 70°C 26.3 3 (e) (b)	10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) x 10 ⁻⁵ (a) 1.4 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161 0-14000 1.62	Max Safe Drop, ft 500-lib General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lib General Purpose B Height, ft Trials Unaffected	500 comb vs Ceneral No Seal 4,000 26 24 2 0 comb vs Ceneral No Seal 5,000 21 18 0	00-6000 Ne: Seal 4-5,000 20 0 0 0 ste: Seal 5,000 26 22 0
col/sec/cm/°C Coefficient of Expension: Linear, %/*C =40° =40° =40° Volume, %/*C =27° 16° Herdness, Mohs' Scale: Your-' Medulus: E', synes/cm² E, lb/inch² Density, gm/cc Compressive Strongth: lb Density, gm/cc Vapor Pressure:	(b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 ; (e) (b) /inch² 13800	10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) x 10 ⁻⁵ (a) 1.4 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161 0-14000 1.62	Max Safe Drop, ft 500-lib General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lib General Purpose B Height, ft Trials Unaffected	500 comb vs Ceneral No Seal 4,000 26 24 2 0 comb vs Ceneral No Seal 5,000 21 18 0	00-6000 Ne: Seal 4-5,000 20 0 0 0 ste: Seal 5,000 26 22 0
Col/sec/cm/°C Coefficient of Expension: Linear, %/*C =40° =40° =40° 10° Volume, %/*C 27° 16° Mardness, Mohe' Scale: Your-' Vadulus: E', uynes/cm² E, lb/inch² Density, gm/cc Compressive Strength: lb Density, gm/cc Vapor Pressure: *C m 80 85 90	(b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 ; (e) (b) /inch² 13800	10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) x 10 ⁻⁵ (a) 1.4 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161 0-14000 1.62	Max Safe Drop, ft 500-lib General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lib General Purpose B Height, ft Trials Unaffected	500 comb vs Ceneral No Seal 4,000 26 24 2 0 comb vs Ceneral No Seal 5,000 21 18 0	00-6000 Ne: Seal 4-5,000 20 0 0 0 ste: Seal 5,000 26 22 0
cal/sec/cm/°C Coefficient of Expension: Linear, %/°C -40° -40° -40° Volume, %/°C 27° 16° Mardness, Mohs' Scale: Your-' Vadulus: E', uynes/cm² E, Ib/inch² Density, gm/cc Compressive Strongth: Ib Density, gm/cc Vapor Pressure:	(b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 ; (e) (b) /inch² 13800	10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) x 10 ⁻⁵ (a) 1.4 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161 0-14000 1.62	Max Safe Drop, ft 500-lib General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lib General Purpose B Height, ft Trials Unaffected	500 comb vs Ceneral No Seal 4,000 26 24 2 0 comb vs Ceneral No Seal 5,000 21 18 0	00-6000 Ne: Seal 4-5,000 20 0 0 0 ste: Seal 5,000 26 22 0

INT (Trinitrotoluene)

Fregmentation Yest:		Shaped Charge Effectiveness, TNT = 100:	
90 xam HE, M71 Projectile, Let WC-91	e (1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1	Gécus Cones Steel Cones	
Density, gm/cc	1.60	Hice Volume 100 100	
Charge Wt, Ib	2.104	Hole Depth 100 100	
Total No. of Fragments:		Color: Light yellow	_
For TNT	703		
For Subject HE	703	Principal Uses: GP bombs, PE projectiles,	_
3 inch HE, M42A1 Projectile, Let KC-5		demolition charges, depth charges,	
	1.60	grenades, propellant compositions	
Density, gm/cc	0.848		
Charga Wt, Ib	U+040		
Total No. of Fragments:		Author of Lording: 1. Cast	
For TNT	514	Atothod of Leading: 1. Cast 2. Pressed	
For Subject HE	314		
e e		Leading Density: gm/cc See below	
Fragment Velocity: ft/sec	(k)		
At 9 ft At 251/4 ft	8500 8500	Storage:	_
Pensity, gm/cc	1.58		
		Method Dry	
Stast (Kelative to TNT):	······	Hazard Class \(\triangle\tau\) uontity-Distance) Class 9	
Aia		Compatibility Group Group I	
Peak Pressure	100		
Impulse	100	Exudotion None at 65°C	
Energy	100		
Air, Confine.		Loading Density: gm/cc	
Impulse	100	1. Cast 1.58-1.59 2. Pressed psi x 103	
Under Water:		3 5 10 15 20 30 5	0
Peak Pressure	100	1.35 1.40 1.45 1.52 1.55 1.59 1	. (
Impuise	100	Thermal Conductivity:	
Energy	100	cal/sec/cm/OC	
Underground:		Density 1.19 gm/cc (g) 5.28 x 10 4	
Peak Pressure	100	1.51 gm/cc (g) 7.12 x 10 ⁻¹ 1.54 gm/cc (t) 5.6 x 10 ⁻¹	
Impulse	100	1.67 gm/cc (g) 12.21 x 10 ⁻⁴	
Energy	100	Viscosity, poises:	
		Tem, 85°C 0.139	
e de la companya de		Bulk Mcd. J. s at Room	
		Temperature (25°-30°C): (m)	
		Dynes/cm x 10 10 2.92 Density, gm/cc 1.56	

TWT (Trinitrotoluene)

Effect of Temperature on Rate of	of Detons	tion: (1)	
Temperature of Charge, OC	-54	21	۵	60
Sours at Temperature	16	16	24	72
Density, gm/cc	1.63	1.62	1.64	1.64
Pate, maters/second	6700	6820	6770	6510

Sensitivity to Electrostatic Discharge, Joules; Through 100 Mesh:

Unconfined 0.36 Confined 4.4

Impact Sensitivit, versus Temp rature:

Picatincy Arsensi Apparatos, 2 mg wt, inches:

<u> </u>	,		inches		
-40		4 4	17	+ 2	
Room			14		•
80	 		7		
. 90		•	3 , :		
105-110			2 (5 e	explin 20	trials

Demact Sensitivity versus Loading Mathod, Large Espect Apparatus, Inches:

Pressed at 1.60 gm/ce 70 Cast at 50 gm/cr 26

Rifle Fallet Dynes Sensivity versus Tempareture, Confinement:

Standard Iron Bomb:	Room Tempera tur	<u> </u>	105°	to 110°C
No Air Space Trials Explosions	10 1 very low ox	der	4.	10 7
Air Space Trials Explosions	10		¥.	10 0
Tin or Cardboard Bombs:			£.,	
With or Without Air Space Trials Logions	10		\$1	10 0

int (Trinitrotolusse)

Prologion Temperature versus TET Initie Temperature:

THT Temperature, Initial	Explosion Pemperature, OC
Room 105°-100°C	470 (Decomposes) 480 (Decomposes)
plosion Emperature versus Confinement,	, °C:

Unconfined Sealed in glass capillary

Viscosity at 80.5°C:

Viscosity, X, cp log X = 0.046 S + 1.26 S = \$ solid in slurry Particle size effect, small

Density, gw/ce:

<u>°c</u>	State	gra/cc
27 to 70 80	Flaked	1.65
8o 💥	Flaked	1.64
82	Liquid	1.48
`. <u>.</u> 87	Taking a	1.48
.95	Liquid	1.47

Solubility of Ter, gra/100 gra (\$), in: (f)

<u>ila</u>	<u>ter</u>	Ace	tone	<u> 2</u>	enzene	 To	luene
<u>့ ဗ</u> င	_ 1	<u>°c</u> .	£	°C	£	OC :	
0 20 40 60	0.0100 0.0130 0.0285 0.0675	0 20 40 60	57 109 226 600	90 40 60 80	13 67 180 478 >2000	90 90 80 90	28 55 130 367 71700
Č	arbon					The in	hī owo-

	Carbon chloride	<u>Rti</u>	ber	Chlore	oform	Trichlo ethyle
<u>°c</u>	£	°c	2	°c	<u> </u>	0,,
0	0.20 0.35 1.75	0 20	1.73 3.29	0 20 40	6 19 66	25 55
60 70 75	6.90 17-34 24.35			60	302	

TMT (Trinitrotoluene)

Pyr	dine	Methyl	acetate		vlene loride		boxy- acetate
o _C	5	<u>°c</u>	ž	<u>°c</u>	\$	<u>°∟</u>	
20 40 ú0	140 250 640	20 40 50	73 135 260	20 40 60	34 123 460	20 40 50	29.5 49 96
70	1050	•				_	

	chloro-	. At	niline		bol	Ethe	anol
<u>ိင</u>	ź	°c	ž	°c	£	<u>်</u> င	2
20 40 50	18 50 100	10 30 50 70 80	6.1 11.5 29 74 130	20 40 50	0.76 1.96 2.95	o 20 40 60 70	0.62 1.25 2.85 8.4 15

Isobutyl	alcohol	Carbon d	isulfide	Chloro	benzene
<u>°c</u>	£	<u>°с</u>	. 2	<u>°c</u>	ž
0	0.20	0	0.14	20	5 5
20	0.61	20	0.44	3 €	51
40	1.41	40	1.4	40	79
50	2.35			50	116

Preparation.

(AC 7258, 7259, 7260 - Mitration Kinetics) (Chemistry of Powder and Explosives, Davis)

In older processes trinitrotoluene (TMT) was slowly and laboriously nitrated in three stages using successively stronger acids. Today, however, a single stage nitration is possible, in a short time (less than one hour) producing TMT at a cost of a little less than 66/lo. In England, a two stage continuous process was developed during World War II; in the first counter current stage, to me was nitrated to the mono stage mononitrotoluene (MMT); in the second stage, also count current, MMB was nitrated to TMT.

TNT (Trinitrotoluene)

It was the British work, on the kinetics of nitration of toluene to TNT, that first pointed out the basic importance to nitration processes of the nitroxyl ion (NO_2^+) , on the one hand, and the role of the bisulfate ion (RSO_4^+) and unionized sulfuric acid on the other. These concepts were successful in explaining the maximum in nitration rate occurring at a sulfuric acid content of 92%. This work, for instance, leads to the following equation for the rate of formation of TNT from DNT:

$$\frac{q \left(LML\right)}{q \left(LML\right)} = K \left(H0^{5+}\right) \left[K, \left(H20^{\beta}-\right) + K, \left(H^{5}20^{\beta}\right)\right] \left(LML\right)$$

Inree Stage Process: Toluene (100 gm) is nitrated to the mono derivative by slowly adding a mixture of 294 gm sulfuric acid (sp gr 1.84) and 147 gm nitric acid (sp gr 1.42) to it at 30°-40°C, with good agitation. Acid addition requires 1-1.5 hour, and stirring at 30°-40°C is continued 30 minutes longer. The mixture is cooled and the lower layer of spent acid drawn off.

Half the crude mono is dissolved in 109 gm sulfuric acid (sp gr 1.84) with cooling, the solution heated to 50°C and a mixture of 54.5 gm nitric acid (sp gr 1.50) and 54.5 gm sulfuric acid (sp gr 1.84) added, under agitation, at such a rate that the temperature is maintained between 90° and 100°C. Acid addition requires 1 hour, and stirring at 90°-100°C is continued 2 more hours.

While the dinitration mixture is still at 90°C, 145 gm fuming sulfuric acid (cleum containing 15% free SO₃) is added slowly. A mixed acid of 92.5 gm each nitric acid (sp gr 1.50) and 15% cleum is slivly added, under good agitation at 100°-11 'over 1½-2 hours. The mixture is stirred at 100°-115°C for 2 more hours, cooled, filtered, and the TMT cake broken up and washed with water. The TMT is washed 3-4 times with hot water (85°-95°C) with good agitation. The project can be purified either by recrystallization from alcohol or by washing it with 5 times its weight of 5% sodium bisulfite solution at 90°C for ½ hour with vigorous stirring, washing with hot water until the washings are colorless, and cooling slowly with stirring to granulate the product.

Origin:

TWT was first prepared in 1863 by Wilbrand (Ann 128, 178), later by feilstein and Kuhlberg (Ber 3, 202 (1870) and also Tiemann (Ber 3, 217 (1870), each using different methods of starting materials. It was nearly 30 years later when Hausermann undertook its manufacture on an industrial scale (Z angew Chem, 1891, p. 508; J Chem Ind., 1891, p. 1028). After 1901 TWT began to be used extensively as a military explosive and Germany became the first nation to adopt it as a standard shell filler (1902-1904). During World War I all the major powers of the world were using TWT, with the quantity used limited only by the available supply of toluene. Prior to World War II the development of synthesic toluene from petroleum made available in the United States, an almost unlimited supply of this raw material. Because of the general suitability of TWT for melt-loading and its extensive use in binary and ternary explosive mixtures, TWT is considered the most important military explosive known today.

Destruction by Chemical Decomposition:

THT is decomposed by adding it slowly, while stirring, to 30 times its weight of a solution prepared by dissolving 1 part of sodium sulfide (Ma_2S-9H_2O) is 6 parts of water.

References:75

(a) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

⁷⁵See footnote 1, page 10.

TWT (Trinitrotoluene)

- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Rovision, MAYORD Report Mo. 87-46, 26 July 1946.
- (c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, HOL Nemo 10,303, 15 June 1949.
- (d) L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Parformance Tests, OSED Report No. 5746, 27 December 1945.
 - (e) Report AC-2587.
 - (f) International Critical Tables and various other sources in the open literature.
- (g) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity of Explosive Materials, AC-2501, First Report, August 1942.
 - (h) A. J. B. Robertson, Trans Parad Society, 44: 977 (1948).
- (i) M. A. Cook and M. T. Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem (June 1956), pp. 1090-1095.
- (j) Committée of Div 2 and 8, NDRC, Report on NET and Tritonal, OSRD No. 5406, 31 July 1945.
- (k) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.
- (1) W. J. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR Ro. 2353, November 1956.
- (m) W. S. Cramer, "wilk Compressibility Data on Several High Emplosives, NAVORD Report No. 4380, 15 September 1956.
 - (n) Kentrov, Journal of Chemical Industry (Russia) 6, 1929, pp. 1686-1688.
 - (o) Also see the following Picatinny Argenal Technical Reports on TRT:

0 0	1	2	3	4	2	<u>6</u>	1	<u>8</u>	2
10	291	132	43	364	65	86	47	118	: 99
30 240	551	582	83	694	195	266	87	283	249
240	731	782	133	874	125	556	507	638	269
350	861	892	273	904	555	556 666	527	738	319
630	891	972	513	1094	695	956 986	597	768	389
760	901	1072	643	1104	735	986	707	838	499
810	971	1182	673	1124	805	1046	807	1388	709
1120	1041	1192	743	1224	975	1146	817	1098	739
1140	1121	1272	853	1284	1145	1276	537	1128	779
1170	1311	1292 1342	863	1294	1155	1376	1107	1148	799
1260	1391	1342	1063	1304	1225	1446	1147	1158	889
1270	1431	1352	1123	1314	1285	1466	1217	1188	929
1360	1451	1372	1133	1344	1305	1476	1247	1198	939
1460	1491	1402	1193	1414	1315	1556	1307	1228	1099
1460	1651	1452	1243	1444	1395	1636	1417	1258	1109
1500	1821	1472	1,23	1454	1425	1756	1427	1308	1129

AMCP 706-177 TMT (Trinitrotoluere) <u>6</u> 1435 1445 1495 1515 1535 1565 1665 1665 1865 1715 1885 2125 2175 <u>e</u> <u>4</u> I 1562 1582 1712 1862 2216 1540 1550 1730 2010 2100 2160 1493 1553 1633 1693 1823 2063 2163 1544 1564 1604 1674 1754 1924 2064 1457 1497 1537 1547 1557 1577 1577 1677 1737 1797 1827 1847 2007 2147 2167 1336 1368 1418 1426 1576 1618 1688 1726 1826 1838 2008 2136 2168 1179 1259 1289 1369 1379 1419 1429 1469 1529 1629 1749 1749 1809 1819 1819 1949 2159 2179

Torpex

Composition:		Molecular Weight:	97
RDX	42	Oxygen Belence:	
TKT	40	CO: %	-55 - 2 6
Aluminum	18	Density: gm/cc Cast	1.76-1.81
		Mailing Point: *C	
C/H Ratio		Freezing Point: "C	
Impact Sonshivity, 2 Kg Wt:		Beiling Point: *C	
Bureou of Mines Apparatus, cm Sample Wt 20 mg	42	Befreethe Index - D	
Picatinny Arsenal Apparatus, in.	9	Refrective Index, no	
Sample Wt, mg	15	n _m	
		r.	
Friction Pondulum Test:		Vesuum Stability Test:	
Steel Shoe		cc/40 Hrs, at	
Fiber Shoe		90.C	
Diffe Bullet Impact Tests Tests		100.C	
Rifie Bullet Impact Test: Trials		120°C	1.0
% Explosions 20		135°C	
Partials 80	4.	150°C	
		200 Grem Bomb Sond Yest:	
Unaffected 0		Sand, gm	59.5
Explains Temperature: °C		Sessitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
5 Decorposes 260		Mercury Fulminate	0.18
5 Decomposes 260		Leod Azide	
10		Tetry,	
15		Bellistic Morter, % TNT: (a)	
20			138
75°C International Heat Test:		Trouzi Test, % TNT: (b)	164
% Loss in 48 Hrs		Plate Dent Test: (c) Method	В
100°C Heet Test:		Condition	Cast
% Loss. 1st 48 Hrs	0.00	Confined	No
% Loss, 2nd 48 Hrs		Density, gm/cc	1.83
Explosion in 100 Hrs	0.10	Brisance, % TNT	120
Expresion in 100 rits	None		
Flommobility Index:	196	Confinement	None
		Condition	Cast
Hygrescepicity: % 30°C, 90% RH	0.00	Charge Diameter, in.	1.0
		Density, gm/cc	
Velatility:			1.81
		Rate, meter://second	7495

Gos Volume, cc/gm Formation, cal/gm Fusion, cal/gm Specific Meet: cal/gm/°C At -5°C Density, gm/cc At 15°C Density, gm/cc At 15°C Bearing Rete: cm/sec Thermed Conductivity: cal/sec/cm/°C Density, gm/cc Volume, %/°C Mardian: Meins Scale: Young's Modulus: E', dynes/cm ³ Density, gm/cc Density, gm/cc Density, gm/cc 18 Sol inert, Velocity, ft/sec Aluminum Fineness Sol inert, Velocity, ft/sec Aluminum Fineness Sol inert, Velocity, ft/sec Aluminum Fineness Sol inert, Velocity, ft/sec Aluminum Fineness 10 Plate Thickness, inches 11/4 11/4 11/4 11/4 11/4 11/4 11/4 11	Booster Sensitivity Test: Condition	(c) Pressed	Casc	Decemposition Equation: Oxygen, atoms/sec	
Wex, gm 2 0 Density, gm/cc 1.64. 1.81 Heat of: Combustion, col/gm 1800 Gos Volume, cc/gm Formation, col/gm Euplosion, col/gm Fusion, usion Fusion Fusion, col/gm Fusion	Tetryl, gm	10	5		
Wax, gm	Wax, in. for 50% Detant	stion			
Density, gm/cc 1.64 1.81 Phase	Wax, gm	2	0		
Combustion, col/gm 1800 Gas Volume, cc/gm Formation, col/gm Fusion, col/gm Fusion, col/gm Specific Neet: col/gm/*C (b) At -5°C 0.22 Density, gm/ce 1.82 At 15°C 0.24 Barning Rate: cm/sec Thermal Conductivity: col/sec/cm/*C 9.7 x 10 ⁻¹⁶ Density, gm/ce 1.82 Coefficient of Expension: Linear, %/*C -73 to 75°C 4.7 x 10 ⁻⁵ (b) Volume, %/*C -73 to 75°C 4.7 x 10 ⁻⁶ E, ib/inch* 1.38 x 10 ⁶ Density, gm/cc 1.77 Compressive Strength: Ib/inch* (b) 2100-2300 Density, gm/cc Vaper Pressure: Aluminum Fineness 508 Inert, Velocity, ff/sec 18 68 mm Merier Projectile: 50% Inert, Velocity, ff/sec 18 60 mm Merter Projection: 50% Inert, Velocity, ff/sec 18 50% Inert, Velocity, ff/se	Density, gm/cc	1.64	1.81	1	
Explosion, col/gm Gas Volume, cc/gm Formation, col/gm Fusion, Fusion, col/gm Fusion Fusio		(a)		A man Minte I man Man I	
Gos Volume, cc/gm Formaticn, cal/gm Fusion, cal/gm Specific Meet: cal/gm/°C At -5°C Density, gm/cc At 15°C Density, gm/cc At 15°C Thermal Conductivity: cal/sec/cm/°C Density, gm/cc Linear, %/°C -73 to 75°C h.7 x 10 ⁻⁵ (b) Volume, %/°C Wolume, %/°C Fighred Medulus: E, lb/inch² Density, gm/cc Density, gm/cc Thermal Conductivity: cal/sec/cm/°C Density Medulus: E, lb/inch² Density, gm/cc Linear, %/°C Triols Unaffected Low Order Height, ft Triols Unaffected Low Order Height, ft Triols Unaffected Low Order Height, ft Triols Unaffected Low Order Height, ft Triols Unaffected Low Order Height, ft Triols Unaffected Low Order Height, ft Triols Unaffected Low Order Height, ft Triols Unaffected Low Order	Combustion, cal/gm		3740	Armor Fiera Impact 1001:	
Gos Volume, cc/gm Formation, cal/gm Specific Heat: cal/gm/*C (b) At -5°C 0.22 Density, gm/cc 1.82 At 15°C 0.24 Burning Rate: cm/sec Thermal Conductivity: (b) cal/sec/cm/*C 9.7 x 10 ⁻¹⁴ Density, gm/cc 1.82 Coefficient of Expansing: Linear, %/*C -73 to 75°C 4.7 x 10 ⁻⁵ (b) Volume, %/*C Height, ft Trials Unaffected Low Order Height, gm/cc Unaffected Low Order Height, gm/cc Unaffected Low Order Height, ft Trials Unaffected Low Order Height, ft Trials Unaffected Low Order Height, ft Trials Unaffected Low Order Height, ft Trials Unaffected Low Order Height, ft Trials Unaffected Low Order Height, ft Trials Unaffected Low Order Height, ft Trials Unaffected Low Order Height, ft Trials Unaffected Low Order	Explosion, col/gm		1800	60 mm Morter Projection	(•)
Fusion, ca:/gm Specific Meet: cal/gm/*C (b) At -5°C 0.22 Density, gm/cc 1.82 At 15°C 0.24 Surning Rate: cm/sec Semb Drep Test: Thermal Conductivity: cal/sec/cm/*C 9.7 x 10°-14 Density, gm/cc 1.82 Coefficient of Expansing: Linear, %/*C -73 to 75°C 1.7 x 10°-5 (b) Volume, %/*C Volume, %/*C Volume, %/*C Young's Medulus: E', dynes/cm ³ 9.53 x 106 E, lb/inch ³ 1.38 x 106 Density, gm/cc 1.77 Compressive Strength: lh/inch ⁴ (b) 2100-2300 Density, gm/cc 1.77 Value Fressure: Semb Drep Test: T7, 2000-15 Semi-Armor-Piercing Bernb vs Concrete: Height, ft Trials Unaffected Low Order Height, ft Trials Unaffected Low Order	Gas Volume, cc/gm				185
Specific Most: cal/gm/*C (b) At -5°C 0.22 Density, gm/cc 1.82 At 15°C 0.24 Burning Rate: cm/sec Samb Brep Test: Thermal Conductivity: (b) cal/sec/cm/*C 9.7 x 10 ⁻¹⁴ Density, gm/cc 1.82 Coefficient of Expension: Linear, %/*C -73 to 75°C 4.7 x 10 ⁻⁵ (b) Volume, %/*C Wang's Medulus: (b) E', dynes/cm² 9.53 x 10 ⁶ E, lb/inch² 1.38 x 10 Density, gm/cc 1.77 Compressive Strength: lh/inch² (b) 2102-2300 Density, gm/cc Vaper Pressure: Sob th General Purpose Bombs: Plate Thickness, inches 1 1/4 11/4 11/2 13/4 11/4 11/2 13/4 11/4 11/2 13/4 11/4 11/2 13/4 11/4 11/2 13/4 11/4 11/2 13/4 11/4 11/2 13/4 11/4 11/2 13/4 11/4 11/2 13/4 11/4 11/2 13/4 11/4 11/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/4 13/2 13/4 13/4 13/4 13/2 13/4 13/4 13/4 13/4 13/4 13/4 13/4 13/4	Formation, cal/gm			Aluminum Fineness	•
Specific Meet: cal/gm/*C (b) At -5°C 0.22 Plate Thickness, inches Density, gm/cc 1.82 1 At 15°C 0.24 1½ 1½ 1½ 1½ 1½ 1½ 1½ 1½ 1½ 1½ 1½ 1½ 1½ 1	Fusion, ca!/gm			1	
At -5°C 0.22 Plate Thickness, inches Density, gm/cc 1.82 1 1 1 1 1 1 1 1 1	Sandin Mark and an 195	/s\		500-lb Ganaral Puryase Bombs:	•
Surning Rate: Confident of Expansion:		(0)	0.22	Plate Thickness, inches	
Burning Rate: cm/sec Thermal Conductivity: (b)	Density, gm/cc		1.82	1	
Surning Rate: cm/sec	(A 3 E O G		o ob	11/4	
Burning Rate: cm/sec Thermal Conductivity: col/sec/cm/*C Density, gm/cc Coefficient of Expension: Linear, %/*C = 73 to 75°C ¼.7 x 10 ⁻⁵ (b) Volume, %/*C Height, ft Triols Unaffected Low Order i-ligh Order E, dynes/cm² 9.53 x 10 Density, gm/cc 1.77 Compressive Strength: lh/inch² (b) 2109-2300 Density, gm/cc Vapor Pressure: Valume Samb Drop Test: T7, 2000-lb Semi-Armer-Plercing Berab vs Cand Amax Safe Drop, ft 500-lb General Purpose Bemb vs Concrete: Height, ft Triols 1.38 x 10 1000-lb General Purpose Bemb vs Concrete: Height, ft Triols Unoffected Low Order	At 1) C		0.24	· · ·	
Berning Rate: cm/sec Thermal Conductivity: cal/sec/cm/*C 9.7 x 10 ⁻¹⁴ Density, gm/ce 1.82 Coefficient of Expension: Linear, %/*C -73 to 75°C 4.7 x 10 ⁻⁵ (b) Volume, %/*C Height, ft Trials Unaffected Low Order i-ligh Order F, dynes/cm² 9.53 x 10 ⁶ E, lb/inch² 1.38 x 10 Density, gm/cc 1.77 Compressive Strength: lb/inch² (b) 2100-2300 Density, gm/cc 1.77 Vapor Pressure: Samb Drop Test: T7, 2000-ib Semi-Armor-Plorcing Bernb vs Concrete: Height, ft Trials Unaffected Low Order i-ligh Order 1000-ib Genural Purpose Bamb vs Concrete: Height, ft Trials Unaffected Low Order Unaffected Low Order				·-	
Thermal Conductivity: (b) cal/sec/em/*C Density, gm/cc Coefficient of Expension: Linear, %/*C -73 to 75°C 4.7 x 10 ⁻⁵ (b) Volume, %/*C Young's Medulus: (b) E', dynes/cm² 9.53 x 10 ⁶ E, lb/inch² 1.38 x 10 Density, gm/cc Compressive Strength: lb/inch² (b) 2100-2300 Density, gm/cc Vapor Pressure: T7, 2000-ib Semi-Armor-Plorsing Bornb vs Const Max Safe Drop, ft S00-ib Gensrel Purpose Bomb vs Constructe: Height, ft Trials Unaffected Low Order i-ligh Order Height, ft Trials Unaffected Low Order Trials Unaffected Low Order				•	
Coefficient of Expension: Linear, %/°C -73 to 75°C 4.7 x 10 ⁻⁵ (b) Volume, %/°C Young's Medulus: E', dynes/cm² 9.53 x 10 E, lb/inch² 1.38 x 10 Density, gm/cc Compressive Strength: lh/inch² (b) 2100-2300 Density, gm/cc Vapor Pressure: T7, 2000-lb Semi-Armer-Ploreing Bornb vs Concrete: Max Safe Drop, ft S00-lb General Purpose Bomb vs Concrete: Height, ft Triois Low Order i-ligh Order 1.000-lb Genural Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order Trials Unoffected Low Order				Somb Drop Test:	
Coefficient of Expension: Linear, %/°C -73 to 75°C 4.7 x 10 ⁻⁵ (b) Volume, %/°C Height, ft Trials Unaffected Low Order F, dynes/cm² 9.53 x 10 E, lb/inch² 1.38 x 10 Density, gm/cc Tous Generate: Max Safe Drop, ft S00-th Generat Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order Fligh Order 1.77 Height, ft Trials Unoffected Low Order Fligh Order 1.77 Unoffected Unoffected Low Order Low Order Low Order	cal/sec/cm/°C	(b) 9		T7, 2000-15 Semi-Armor-Plotting Born	b vs Concrita:
Volume, %/°C Height, ft Triois Unaffected Low Order High Order I 38 x 10 Density, gm/cc Veper Pressure: Height, ft Triois Unaffected Low Order High Order 1.38 x 10 1.000-th Genural Purpose Bamb vs Concrete: Unoffected Low Order Height, ft Trials Unoffected Low Order Low Order Unoffected Low Order				Max Safe Drop, ft	
Young's Medius: (b) E', dynes/cm² 9.53 x 10 E, lb/inch² 1.38 x 10 Density, gm/cc 1.77 Compressive Strength: lh/inch² (b) 2100-2300 Density, gm/cc 1.77 Vapor Pressure: Preight, Trials Unaffected Low Order iligh Order 1000-th Genural Purpose Bamb vs Concrete: Height, ft Trials Unaffected Low Order	Linear, %/°C -73 to	75°C 4.7 x 10	o ⁻⁵ (b)	500-7b General Purpose Bemb vs Con-	crefe;
Young's Medicia: E', dynes/cm² 9.53 x 10 E, lb/inch² 1.38 x 10 Density, gm/cc 1.77 Compressive Strength: lb/inch² (b) 2100-2300 Density, gm/cc 1.77 Unaffected Low Order High Order 1.000-lb Genural Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order	Volume, %/°C			Height, ft	
Voung's Mediulus: E', dynes/cm² 9.53 x 106 E, lb/inch² 1.38 x 10 Density, gm/cc 1.77 Compressive Strength: lh/inch² (b) 2100-2300 Density, gm/cc 1.77 Vapor Pressure: Unaffected Low Order High Order 1.000-th Genural Purpose Bamb vs Concrete: Unaffected Low Order		~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~		Trials	
Young's Modulus: (b) E', dynes/cm² 9.53 x 106 E, lb/inch² 1.38 x 10 Density, gm/cc 1.77 Compressive Strength: lb/inch² (b) 2100-2300 Density, gm/cc 1.77 Vapor Pressure: Low Order High Order 1.000-lb Genural Purpose Bamb vs Concrete: Unoffected Low Order	Mardia Maine Scole:			Unaffected	
E', dynes/cm² 9.53 x 106 E, lb/inch² 1.38 x 10 Density, gm/cc 1.77 Compressive Strength: lh/inch² (b) 2100-2300 Density, gm/cc 1.77 Vapor Pressure: (b) iligh Order 1000-th Genural Purpose Bomb vs Concrete: Height, ft Trials Unoffected Low Order				Low Order	
E, lb/inch² Density, gm/cc 1.38 x 10 1.000-lb Genural Purpose Bomb vs Concrete: Height, ft Trials Unoffected Low Order	•	(b)	10	1	
Density, gm/cc 1.77 Compressive Strength: lh/inch² (b) 2100-2300 Density, gm/cc 1.77 Height, ft Trials Unoffected Low Order	• •	9.53	x 10_6	1.1.	
Density, gm/cc 1.77 Height, ft Compressive Strength: lh/inch² (b) 2100-2300 Density, gm/cc 1.77 Height, ft Trials Unoffected Low Order		-		1000-lb General Purpose Bomb vs Con-	crate;
Compressive Strength: It/inch² (b) 2100-2300 Density, gm/cc 1.77 Vapor Pressure: Trials Unoffected Low Order	Density, gm/cc	;	L.77		
Density, gm/cc 1.77 Unoffected Vapor Pressure: Low Order	Compressive Strengths It /inc	hi (b) 2100	0-2300	1	
Vapor Pressure: Low Order				1	
			11	1	
mm Mercury High Order					•
	TC mm A	Aercury		High Order	
l l					

Fregmentation Test:		Sheped Charge Effectiveness, TNT = 1 50/36.5/13.	00: 5
90 mm HE, M71 Projectile, Let W	C-01:	Glass Cones Sterl (
Density, grn/cc	1.75	Hole Volume 150 14	5
Charge Wt, Ib	2.316	Hole Depth 127 13	1
Total No. of Fragments:		Color:	Gray
For TNT	703	•	Olay
For Subject HE	891	Principal Uses: Depth charges, be	omba
3 lack HE, M42A1 Projectile, Let	KC-5:	pepul unitable, t	
Density, gm/cc	1.79		
Charge Wt, Ib	0.940		
Total No. of Fragments:		Method of Leading:	Cast
For TNT	514		
For Subject HE	647	Leading Density: gm/cc	1.76-1.81
Fregment Velocity: ft/sec		Lessing Genny: gm/cc	1110-1101
Át 9 ft	2960 28 0 0		
At 251/4 ft		Storage:	
Density, gm/cc		Method	Dry
Black (Relative to TNT):	(e)	h'nzard (Joss (Quantity-Distance)	Class 9
Ain		Compatibility Group	Group I
Peak Pressure	122	i	
Impulse	125	\"xudation	
Energy	146		
Air, Confined:	116	Effect of Temperature on Impert Sensitivity:	
•		Tem. PA Inpact Test	
Under Weter:	226	2 Kg Wt, inches	
Peak Pressure	116	25 15	
Impulse	127	i 32 7	
Energy	153	104	
Underground: Peak Pressure		Viscosity, poises:	
Impulse		Т ещ р, 83 ⁰ С	4.5
Energy		95°C	2.3
		1	

Preparation:

Torpex is manufactured by heating TNT to approximately 100°C in a steam-jacketed kettle equipped with a stirrer. Water wet RDK is added slowly to the molten TNT, while mixing and heating, until all the water is evaporated. Aluminum is added and the mixture is stirred until uniform. The mixture is cooled, with continued attring, until it is suitable for pouring. Torpex can also be made by adding the calculated amount of TNT to Composition B to maintain the desired proportion of RDK/TNT, heating and stirring, and adding 18 percent of aluminum to complete the mixture.

Origin:

Turpex, a castable high explosive, was developed in England during World War II for use as a filler in warheads, mines and depth bombs. Several variations in the composition of torpex have been evaluated but the following are those used in survice munitions:

	Torpex 2 unwared	Torpex 2 waxed	Trans. 3
	(a)	(b)	(c)
RIX, \$ THT, \$ Aluminum, \$ Wax. \$ Calcium chloride, \$	42 40 18	41.6 39.7 18.0 0.7	41.4 39.5 17.9 0.7 0.5

- (a) Made from Composition B-2 or 60/40 Cycletol.
- (b) Made by the addition of aluminum to Composition B.
- (c) Made by the addition of calcium chloride to Torpex 2.

Wax has the undesirable effect of (1) tending to congulate the aluminum, thus giving a less homogeneous and more viscous product, (2) lowering the density of the cast explosive from 1.72-1.75 to 1.56-1.70 for waxed torper, and (3) lowering the compressive strength from 3700 psi to 1970 psi for waxed torper. However, wax is used in service torpex for reasons of safety, since there is evidence that its presence lowers the sensitivity of the explosive to impact as measured by laboratory drop tests and bullet sensitivity tests of small charges (Bureau of Ord Res Memo Rpt No. 24, January 1945).

References: 76

- (a) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.
- (b) Philip C. Keenan and Dorothy C. Pipes, Table of Military High Explosives, Second Revision, HAVORD Report No. 87-46, 26 July 1946.
 - (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.

⁷⁶See footnote 1, page 10.

Torpe:

- (d) G. H. Messerly, The Exte of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.
- M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.
- (e) 1. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1980.
- (f) Eastern Laboratory du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, MIRC Contract W672-0RD-5723.
 - (6) Also see the following Picatinny Arsenal Technical Reports on Torpex:

8 <u>6</u> 1 <u>o</u> <u>1</u> 2 ٤ 2 1585 1635 1885 2355 18**38** 1651 1796 1797 1530 1292 2353



1,3,5-Triamino-2,4,6-Trinitrobenzene (TATMB)

Composition:		Melecular Weight: (C6E6N606)	258
с 27.9 н 2.3 о ₂ м —	NH ₂ NO ₂	Oxygen Balense: CO ₂ % CO %	-56 -19
и 32.6 н ₂ и	NH ₂	Ecosity: gm/cc Crystal	1.93
0 37.2	NO ₂	Melhing Point: °C 330 (b, e)	360 (a)
C/H Ratio 0-302	-	Freezing Point: *C	
Impact Sonsitivity, 2 Kg Wt:		Beiling Paint: *C	
Bureau of Mines Apparatus, cm Somple Wt 20 mg Picatinny Arsenal Apparatus, in Sample Wt, mg	11 7	Refrective ludes, nº nº nº nº nº nº nº nº nº nº nº nº nº	
Friction Pendulum Test: Steel Shoe Fiber Shoe		Vecuum Strhillity Test: cc/40 Hrr. at 90°C	
Riffe Buller Impact Test: Trials %	•	100°C (a, b) 120°C 135°C	0.36
Explosions Partials		150°C	****
Burned Unaffected		200 Gram Bomb Sand Toot: Sand, gm	42.9
Explesion Temperature: *C Seconds 0.1 (no cop used) 1 5 10	-	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	0.30
15 20		Prilistic Mexter, % TNT:	
		Trough Took, % FNT:	
75°C International Heat Test: % Loss in 48 Hrs		Plate Dest Test: Method	
100°C Heat Test:		Condition	-
% Loss, 1st 48 Hrs	0.00	Confined	
% Loss, 2nd 48 Hrs	0.00	Density, gm/cc Drisonce, % TNT	
Explosion in 100 Hrs	None		
Flammability Index:		Detenation Rate:	None Pressed
Hygrenee, leity: %		Charge Diameter, in.	0.5
Yeletility:		Density, gm/cc Rate, meters/second	1.60 -7500

AMCP 766-17

Programmation Test:	Shaped Charge Effectiveness, TN	ľ = 100:
90 mm 162, MF1 Projectio, Let WC-01:	Glass Cones S	iteel Cones
Density, gm/cc	Hole Volume	
Charge Wt, Ib	Hole Depth	
Total Ha. of Fragments:	Colors	Yellow
For TNT .		141104
For Subject HE	Principal Uses:	
3 Inch ME, MARAT Frejectile, Let ICC-5:		
Density, gm/cc		
Charge Wt, Ib		
Total He. of Fregments:	Method of Loading:	Presso
For TINT	· · · · · · · · · · · · · · · · · · ·	Presso
For Subject HE		
	Leeding Dunelty: gm/cc	_
Fragingat Valority: ft/sec	At 50,000 pai	1.80
At 9 ft At 25½ ft		
	Storege:	
Density, gm/cc	Method	Dry
Plast (Relative to THT):	Hozard Class (Quantity-Distance	•)
Aire	Compatibility Group	
Peak Pressure		
Impulse	Exudation	
Enurgy		
Alt, Confined:	Detonation Velocity:	(a, b. c)
Impulse	Deneity on/on	Matana / sida
-	Density, gm/cc	Meters/sec
Under Weter	1.290	5 380
Peak Pressure	1.345 1.675	56 2 8 6550
Impulse	1.575	6575
Energy	1.882	7035
Underground:	1.835	7223
Peak Pressure	Heat of:	
Impulse	-	
Fnergy	Explosion, cal/gm	2831

1,3,5-Triamino-2,4,6-Trinitrobensene (DATES)

Preparation:

(a)

Absolute alcohol (200 milliliters) was saturated with associa and then 12.5 gm (0.028 mol) of 1,3,5-tribrono-2,4,6-trinitrobensene, prepared according to Hill (MAVOHO Report Ho. 3709, 2 February 1953), was added. The flask was stoppered and allowed to stand at room temperature for a day. Additional associa was bubbled into the mixture, which was then heated under reflux for thirty sinutes, filtered hot, and the insoluble product collected on a Buches funnel. The product was mashed with water, alcohol, and dried. The 4.7 gm of material recovered was recrystallised from nitrobensene.

A disadvantage of the above method was that it could not be used for the preparation of large quantities of TATES. Since it did not seen fearible to develop a new sethod of preparation, an investigation was made of the reported amination reactions (see <u>Origin</u> below). An attempt was made (Ref f) to find a modification which would produce high yields of a pure product. The process which evolved from this study may be summarized as follows (Ref 2): 1,3,5-trichlorobensene was nitrated "in one step" to 1,3,5-trichloro-2,4,6-trinitrobensene in 85% yield. The crude nitration product was aminated in benzene with ammonia gas so DiTES, in yields of at least 95%.

Origin:

TATUS was prepared for the first time in 1888 by C. L. Jackson and J. F. Wing, who f and the compound insoluble in alcohol, ether, chloroform, benzene, and g'acial acetic acid; and soluble in nitrobenzene and sniline (Amer Chem Journal 10, 262 (1868)). B. Flurscheim and E. L. Holmes prepared TATUS from benzene free pentanitromilline by gradually adding it to 10% aqueous amonia (J Chem Soc, Pt 2,30% (1926)). After boiling, an orange-yellow powder melting above 300°C was obtained. This product corresponded to that described by Jackson and wing. These authors, as well as Palmer (Amer Chem Journal 14, 378 (1892)), attempted to reduce TATUS to hem-sminobenzene. Rither decomposition occurred or a hydrochlorids of penta-aminobenzene was formed. Flursch. 4 and Holmes succeeded in reducing TATUS with pastagle-leasine by heating them together up to 200°C (J Chem Soc, Pt 1,334 (1929)) (Bril 12, 301 a.d EII, 147).

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- (a) F. Taylor, Jr., Synthesis of May High Explosives II, Derivatives of 1,3,5-Tribromo-2,4,6-Trinitrobenzume, MAYORD Report No. 4405, 1 Movember 1956.
- (b) L. D. Hampton, Small Scale Detonction Velocity Measurements from May 1951 to May 1954, MAYORD Report No. 3731, June 1954.
- (c) E. M. Fisher and E. A. Christian, Explosion Effects Data Cheets, MAYORD Report No. 2986, 14 June 1955.

⁷⁷See footnote 1, page 10.

CityONO2	Welconfer Melalit: (CRITENSOE,	240
С 59.9 н ⁵ С	Oxygen Belenteu: CO2 % CO %	-89 -27
H 11.7	Dencity: gm/cc 20°C 25°C	1:33 1:32
0 53.0 H ₂ C 0	Mobiling Point: *C	
C/H Ratio 0.17; H ₂ C CH ₂ ONO ₂	Preexing Point: 'C	
Respect Sensitivity, 2 Kg Wit: Stureou of Mines Apparetus, cm 100+	Bulling Point: *C	
Somple Wt 20 mg Picotinny Asserol Apparatus, in. 43 Sample Wt, mg	Refrective Index, no. no. no.	1.4540
Frietlen Pendulum Test:	Vecuum Stebility Test:	
Shed Shee Unaffected Fiber Shee Unaffected	cc/40 Hrs, at 90°C	
Riffe Bullet Impact Test: Trials	100°C 8 hours	0.45 0.8
C % Explosions	135°C	0.0
Portiols	150°C	
Burned	200 Gram Bomb Sand Test:	
Unaffected	Sond, gm	14.7
Explosion Temperature: *C Seconds, 0.1 (no cop used)	Sensitivity to Initiation: Minimum Detonating Charge, gm	
1 5 223	Mercury Fulminate	
10	Lead Azide Tetryl	
15		
20	Ballistic Merter, % TNT:	
75°C International Heat Test:	Treuzi Test, % TNT:	
% Loss in 48 Hrs	Plate Dent Test: Method	
160°C Heat Test:	Condition	
% Loss, 1st 48 Hrs 1.8	Confined	
% Loss, 2nd 48 Hrs 1.6	Density, gm/cc Brisance, % TNT	
Explosion in 100 Hrs None		
Flemmubility Index:	Detenation Rate: Confinement	Shelby steel
	Condition	Liquid
Hygrescepicity: %	Charge Diameter, in.	1.25
Valuabley: 60°C, mg/cm²/hr 40	Density, gm/cc	1.33
Valuability: 60°C, mg/cm²/hr 40	Rate, meters/secund	Fails

Triethylene Glycol Dinitrate (TEGN) Liquid

	*	* * .			
Fragmentation Test:		Shoped Charge	Effectiveness,	TNT = 100:	
90 mm HE, M71 Projectile, Let WC-91:			Glass Cones	Steel Cones	
Density, gm/cc		Hale Volume	1		
Charga Wt, Ib		Hole Depth			
Total No. of Fragments:	F	Color:			
For TNT					
For Subject HE	-	Principal Uscs:	Ingredient	of rocket and	double
3 inch HE, M42A1 Projectile, Let KC-5:	i	•	base prope		
Density, gm/cc	l				
Charge Wt, Ib					
Total No. of Fragments:	, , <u>, , , , , , , , , , , , , , , , , </u>				
For TNT		Method of Load	ling:		
For Subject HE					
-		Looding Density	r: gm/cc		
Fragment Volacity: ft/sec					
At 9 ft At 25½ ft	Γ	Storage:			
Density, gm/cc	[_			
	1	Method		Liqu	ui1 d
Siest (Relative to TNT):		Hazard Class	(Quantity-Dist	rance)	
Aire		Compatibility	Group		
Peak Pressure	1				
Impulse	j	Exudation			
Energy	į.	a-1-1-11-1	***		
Air, Confined:		Solubility in gm/100 gm, at			
Impulse	1'	25°C		0.5	5
		60°C		0.6	
Under Weter: Peck Pressure		Solubility, g	m/100 gm,		
Impulse		at 25°C, in:		_	
Energy		Ether Alcohol		**	
		2:1 Ether:A	lcohol	•	
Underground:		Acetone		~	
Peak Pressure	1	Viscosity, ce			
Impulse		Temp, 20°C		13.	2
Energy		Hydrolysis, %			••
Heat of:		10 days at 5 days at	90₀C 55₀C	0.0	
	428	Vapor Pressur			
Explosion, cal/gm Gas Volume, cr/gm	357 851	o _C	_	mm Merciu	r <u>y</u>
CAR TULING CITHE					

Origin:

Lourence prepared triethylene glycol in 1863 by reading glycol with ethylene bromide in a sealed tube at 115°-120°C (Ann (3) 67, 275). Later in the same year Mirtz prepared triethylene glycol by heating ethylene oxide with glycol at 100°C. By action of nitric acid triethylene glycol was oxidized to (H2000°CH2°0°CH2) (Ann (3) 69, 331, 351).

The Germans and Italians were the first to prepare and use TEGN during World War II as an ingredient of rocket and propellant powders. The commercial production of TEGN in quantity is still difficult and its use as a plasticizer for nitrocellulose is being replaced by other liquid nitrates.

Preparation:

Triethylene glycol is purified by fractional distillation under vacuum in an 18-inch Vigeaux fractioning column. The assembly as a whole is equivalent to 4.5 theoretical plates. The distillation is conducted using a 5 to 1 reflux ratio, at a pot temperature of approximately 180°C, and a take-off temperature of approximately 120°C.

The purified triethylene glycol (TEG) is nitrated by carefully stirring it into 2.5 parts of 65/30/5 nitric acid/sulphuric acid/water maintained at 0 ± 5°C. The rate of cooling is sufficient that 300 gm of TEG can be added within 40 minutes. The mixture is stirred and held at 0 ± 5°C, for 30 additional minutes. It is then drowned by pouring onto a large quantity of ace and extracted three times with ether. The combined extract is water-washed to a pH of about 4, shaken with an excess of sodium bicarbonate solution, and further washed with 1% sodium bicarbonate solution until the washings are colorless. The ethersal solution is water-washed until it has the same pH value as distilled water. It is careful separated from excess water, treated with chemically pure calcium chloride to remove dissolved water, and filtered. The ether is removed by bubbling with dry air until a minimal rate of loss in weight is attained. The yield is 1.34 gm per gm TEG (84% of theoretical) and the nitrogen content of different batches range from 11.60 to 11.69% by the nitrometer method (calculated 11.67%).

References: 78

(a) See the following Picatinny Arsenal Technical Reports on TEGN:

<u>3</u>	5	<u>6</u>	I	<u>8</u>
1953 2193	1745	1786 205 6	1767 1817	1638

⁷⁸See footnote 1, page 10.

Trimonite

Composition:	Melecular Weight:	217
•	Oxygen Balence:	
Pierie Acid 88 - 90	CO. %	-62 -14
Mononitronaphthalene 12 10		
•	Dennity: gm/cc Cast	1.60
	Molting Point: *C	90
C/H Ratio	Freezing Point: *C	
Impact Sensitivity, 2 Kg Wt:	Boiling Point: *C Explodes	300
Bureau of Mines Apparatus, cm 60 Sample Wt 20 mg	Refrective index, no	
Picatinny Arsenal Apparatus, in. 10		
Sample Wt, ring	n _a	
	n _s .	
Friction Pendulum Test:	Vocuum Stability Test:	
Steel Sale	cc/40 Hrs, at	
Fiber Shoe	90°C	
Rifle Bullet Impact Test: Trials	100°C	
%	120°C	0.9
Explosions 0	135°C	
Portiols 0	150°C	
Burned 0	200 Grem Bomb Sond Test:	
Unaffected 100	Sond, gm	44.2

Explosion Temperature: "C Seconds, 0.1 (no cap used)	Sensitivity to Initiation:	
1	Minimum Detonating Charge, gm	
5 Decomposes 315	Marcury Fulminate	
10	Leod Azide	0.20
15	Tetryl	0.04
20	Ballistic Morter, % TNT:	
	Treusi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test:	
	Method	
186°C Heat Test:	Condition	
% Loss, 1st 48 Hrs	Confined	
% Loss, 2nd 48 Hrs	Density, gm/cc	
Explosion in 100 Hrs	Brisance, % TNT	·
Flommability Index:	Detenation Rate:	
rammeomsy (ACCA;	Confinement	None
Hygrecospicity: %	Condition	Cast
ту ргоосорган у: 70	Charge Diameter, in.	1.0
	Density, gm/cc	1.60
Veletility:		

Trimonite

Fragmontation Test:	Sheped Cherge Effectiveness, TNT = 10)O:
90 mm HE, M71 Projectile, Let WC-91:	Glass Cones Steel C	ones
Density, gm/cc	Hole Volume	
Charge Wt, Ib	Hole Depth	
Total No. of Fragments:	Calac	
For TNT		
For Subject HE	Principal Uses: TNT substitute in	projectiles
3 inch HE, M42A1 Projectile, Let KC-5:	and bombs	
Density, gm/cc		
Charge Wt, lis		
Terel No. of Fragments: For TNT	Method of Looding:	Cast
For Subject I-IE		
	Leeding Dessity: gm/cc	1.60
Fragment Velocity: ft/sec		
At 9 ft At 25½ ft	Storage:	
Density, gm/cc		
	Method	Dry
Blast (Relative to TNT):	Hozard Class (Quantity-Distance)	Class 9
Air:	Compatibility Group	Group I
Peak Pressure	_	0-
Impulse	Exudation Exc	des at 50°C
Energy		
Air, Confined:	Preparation:	
Impulse	Picric acid and alpha-mononit	ronaphthalena
Under Water:	are melted together in an alumin	
Peak Pressure	Jacketed melt kettle equipped wi Although picric scid slone requi	res a high tem-
Impulse	perature for its melt loading (1	20°C), the
Energy	mixture forms a cutectic melting must be taken to prevent the for	mation of dan-
Underground: Paok Pressure	gerous metallic picrates. Trime interest as an emergency substit	mits is of
Impulse		
Energy		

Trimonite

Origin:

Trimonite, a castable mixture of picric acid/mononitronaphthalene was developed by the British during World War II as an improvement over tridite which is a mixture of 80/20 picric acid/dinitrophenol. Both mixtures are suitable for melt-loading below 100°C and therefore represent an improvement over melt-loading picric acid alone (melting point 122°C). However, tridite is slightly inferior to picric acid as an explosive and dinitrophenol is objectionable because of its toxicity. Trimonite is also slightly inferior to picric acid and TMT as an explosive. Because of the low eutectic temperature of the picric acid-mononitronaphthalene mixture (49°C), Tridite exudes when stored at elevated temperatures. It does not possess the disadvantages of picric acid (corrosive action on metals, ease of decomposition, etc.) and is a comperatively inexpensive substitute for TMT.

References: 79

(a) See the following Picatinny Arsenal Technical Reports on Trimonite:

2	<u>5</u>	<u>6</u>	<u>8</u>
1352	1325	9 2 6	1098
1372		9 7 6	18 3 6

⁷⁹See footnote 1, page 10.

Composition:	Melerator Weight: ((6H6N6014)	3 66
c 18.6	Oxygen Belence:	
	CO ₃ %	-4.2
H 1.6 .	CO %	20. 8
N = 21.8 $C = 0$ $C = 0$	Density: gm/cc Form I	1.78
0 58.0	Melting Point: *C	93
C/H Rotio 0.202 CH2CH2C(NO2)3	Freezing Point: *C	
Impact Sensitivity, 2 Kg Wt:	Beiling Point: *C	
Bureou of Mines Apparatus, cm Sample Wt 20 mg	Refrective Index, no Form I (e	<u>, </u>
Picatinny Arsenal Apparatus, in.	Crystal Axis	•
Sample Wt, mg	B	1.518 1.5 27
50% point, cm (a) 20	_	1.546
Friction Fondulum Test:	Vacuum Stability Test:	
Steel Shoe	cc/40 Hrs, at	
Fiber Shoe	90°C	
Diffe Bullet Language Tool	- 100°C 48 hrs	0.60
Riffe Bullet Impact Test: Trials	120 C	
% Evaluations	135°C	
Explosions	150°C	
Portiols Burned		
Burned	200 Grem Bomb Send Test:	
Unaffected	Sand, gm	
Englission Temperature:	Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, gm	
1	Mercury Fulminate	
5 50% point (Alhot bar) (a) 225	Leod Azide	
10	Tetryl	
15		
20	Bellistic Morter, % TNT: (b)	136
78°C International Mark Tast	Treuzi Test, % TNT;	
75°C International Heat Test: % Loss in 48 Hrs	Plate Deat Test: Method	
160°C Heat Test:	Condition	
% Loss, 1st 48 Hrs	Confined	
% Loss, 2nd 48 Hrs	Density, gm/cc	
Explosion in 100 Hrs	Brisance, % TNT	
empressor in 199 file		
Flammability Index:	- Datenation Rate: Confinement	
<u>·</u>		
Hygrescapicity: % 30°C, 90% RH 0.00 75°C, 5 months N:1 (a)	Condition	
75°C, 5 months N11 (a)	Charge Diameter, in.	_
Voletility:	Density, gm/cc 1.60	1.76
· = · = · · · · · · · · · · · · · · · ·	Rate, meters/second 7760	8 290

2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate (TNETB)

Boostor Sensitivity	Test:		Decomposition Equation:	
Condition			Oxygen, atoms/sec (Z/sec)	4.4 x 10 ²¹
Tetryl, gm			Heat, kilocalurie/mole	43.4
'Nax, in. for 509	6 Detonation		(AH, kcal/mol)	J .
Wax, gm			Temperature Range, °C	
Density, gm/cc			Phase	Liquid
Heat of: Combustion, cal/	· · · · · · · · · · · · · · · · · · ·	1685	Armer Plate Impact Test:	
Explosion, cal/gr	•	2007		
			60 mm Morter Projectile:	
Gas Valume, o	•	207	50° Inert, Velocity, ft/sec	`
Formation, cal/g	771	307	Aluminum Fineness	
Fusion, cai/gm Sublime+lou,	cal/gm (c.t)	804	500-lb General Purpose Bombs:	
Specific West: cal/g	gm/°C		Plate Thickness, inches	
			1	. ,
			1 '	
			114	
			11/2	
Russian Pater			134	
Burning Rate: cni/sec				
	······		Somb Drop Test:	
Thermal Conductivi cal/sec/cm/*C	ity:		T7, 2000-lb Semi-Armor-Plercing	Bomb vs Concrete:
Coefficient of Exper	esion•		Max Safe Drop, ft	
Linear, %/°C			500-lb General Purpose Bomb vi	Concrete:
Volume, %/°C			Height, ft	
Maniness Make! #-			Trials	
Herdness, Mohs' Sc	UN:		Unaffected	
Young's Modulus:			Low Order	
E', dynes/cm²			High Order	
E, lb/inch²				_
Density, gm/cc			1000-lb General Purpose Bomb v	s Concrete:
			Height, ft	
Compressive Strong	M: Ib/inch²		Trials	
		·	Unaffected	
Vapor Pressure:		(e)	Low Order	
·c	mm Mercury		High Order	
65 75	3.3 x 10 1			
75 85	1.3 x 10 1 4.2 x 10			
1.00	4.2 x 10 3 2.3 x 10 3			
*****	1.4 x 10 ⁻²			

Fregmentation Test:	Shaped Charge Effectiveness, TNT = 100:		
90 mm HE, M71 Projectile, Let WC-97:	Glass Cones Steel Cones		
Density, gm/cc	Hole Volume		
Charge Wt, Ib	Hole Depth		
Total No. of Fregments:	Coloriess		
For TNT			
For Subject HE	Filacipal Uses:		
3 inch HE, M42A1 Projectile, Lc? KC-5:			
Density, g:m/cc			
Charge W ₇ , ib			
Total No. of Fragments:	Method of Looding:		
For TNT	;		
For Subject HE	Leeding Density: gm/cc Form I 1.783		
Fregment Velocity: fr/sec	Form II 1.677		
At 9 ft At 25½ ft	Liquid, 99°C, 1.551 Storage:		
Density, gm/cc	Method Wet		
Sheet (Relative to H-62: Sphere Cylinder (h)	Hazará Class (Quantity-Distance) Compatibility Group Exudation		
Energy			
Air, Confined: impulse Under Weter: Peok Pressure	Bruceton Safety Test Results: (g) Mean and standard deviation of lengths of 0.300 diameter cylinder across which initia- tion is possible for 50% certainty:		
Impulse	TNT 0.391 + 0.640		
Energy	RDX Comp B 0.361 7 0.042 EXETB 0.920 7 0.059		
Underground: Peak Pressure	Absolute Viscosity, poises: (e)		
Impulse	Temp, 98.9°C 0.173		
Energy EW, equivalent weight of H-6 fex a unit weight of test mixture for equal performance at the same test distance; EV, equivalent volume of H-6 for a unit volume of test mixture for equal performance at the same test distance.	1.06.5°c 0.13 8		

2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate (TMETB)

Solubility (Room Temperature):

ì	_	•
£	2	

Solvent	Solubility	
Nater n-Hamne Carbon tetrachloride Ethanol Chloroform Bersene Nitromethano Glacial &cetic acid Ethyl acetate	Insoluble Insoluble Insoluble Insoluble 5 gm/100 gm solvent 5 gm/100 gm solvent 10 gm/100 gm soivent Very soluble Very soluble Very soluble	

TMETS Forms Entectics With the Following Compounds: (a)

BRES (bis(trinitroethyl) succinete) BRES (bis(trinitroethyl) nitramine) THE (trinitroetzene)	57 80+ 68.5 65	
Compound A (ChHcHhO, formed by condensation of 1,1-dinitroethane) Trinitroethyl trinitrobenzoate (27%)	77 80.5 (£)	;

Crystallographic Data:

(a)

Three polymorphic crystalline forms have been observed. Low temperature Form I goes through a solid-solid transition at 89°C giving Form II. Form II has a melting point of 92.5° to 93°C. On cooling, Form II does not transform reversibly to Form I when 89°C is reached. However, Form II will transform to Form I at room temperature, usually taking a few hours to do so. Form III was observed, which appeared to be stable over a vary narrow temperature range on the order of 0.2° to 0.3°C near 92.5°C.

Preparation:

(d)

		(-)	•
(NO ₂) ₃ CCH ₂ CH ₂ COC1 +	(NO ²) 3CH ² OH	H250 ¹	
trinitrobutyryl chloride	trinitroethanol	sulfuric acid	

(No₂) 3 CCH2 CH2 COOCH2 C(No₂) 3

HCl

2,2,2-trinitroethyl-4,4,4-trinitro- hydrochloric butyrate acid

Laboratory experiments indicate that the present slow step involving overnight treatment of 4,4,4-trinitrobutyryl chloride with 2,2,2-trinitrobuthanol and aluminum chloride can be replaced by a fast and simple esterification in sulfuric acid. Using 100% sulfuric acid of fortified H₂SO₆, the ester can be prepared in yields of 95% to 93% in 24 hours at 25°C, in 5 hours at 50°C, or in 3 hours at 65°C. Above 65°C the reaction time is less, but the yield falls off and a less pure product is obtained. The crude white crystalline product on recrystallization from dilute methanol gives a material melting at 92° to 93°C.

2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate (TMETE)

Origin:

(_)

THESE belongs to a new class of explosives characterized by trinitromethyl groups,

-C(Mo₂)₂. The chemistry of this class of compounds was studied in Germany by Drs. Schenck and Softwalschmidt, who discovered in 1942-1945 at trinitromethene or nitroform, MC(Mo₂)₃, was the source of new explosive derivatives. Dr. Schenck prepared the stable solid alcohol, 2,2,2-trinitroethanol, from nitroform and formuldehyde. Dr. Schimmelschmidt reacted nitroform with unsaturated organic compounds, such as acrylic acid, and predicted in 1943 that the exter of 4,4,4-trinitrobutyric acid with trinitroethanol would be an interesting explosive.

In 1947 the U.S. Havy began a program to explore these comporties. The initial task of investigating the chemistry of trinitroethenol was undertaken by the Hercules Powder Company (Many Contract Mord-19,129). The U.S. Rubber Company studied the chemistry of nitroform (Many Contract Mord-10,129). After preparation of the first laboratory samples of TMETB, considerable interest was aroused. In early 1950 the Mangatuck Chemical Division of U.S. Rubber Company was assigned to prepare 100 pounds of TMETB. The Bureau of Ordnance in July 1953 reised the production to 800 pounds with the assistance of the Hercules Powder Company in aug. ing the production at Brugatuck (Havy Contract Mord-11,280). TMETB is a high oxygen content explosive.

References: 80

- (a) J. M. Rosen, <u>Properties of Trinitroethyl Trinitrobutyrate TRETB</u>, MAYORD Report No. 1758, 17 December 1950.
- (b) Bureau of Mines Report No. 3107, Part IX, Ballistic Mortar Tests on Trinitrouthyl Trinitrobutyrate, 5 April 1950.
- (c) L. D. Hampton and G. Svadeba, Evaluation of 2,2,2-Trin troothyl-4,4,4-Trinitrobu', whe at a Constituent of Castable Explosives, MAVCHD Report No. 261, 30 September 1952.
- (d) U.S. Rubber Company Quarterly Progress Report No. 23, 9/nth-sis of New Propellants and Explosives, New Contracts Nord-10-129 and -12,663, 19 August 1/53.
- (e) M. B. Hill, O. H. Johnson, J. M. Rosen, D. V. Sickman and F. Taylor, Jr., Preparation and Properties of TMETB, a New Castable High Explosive, HAVORD Report No. 3885, 27 January 1955.
 - (2) M. E. Hill, Synthesis of New High Explosives, NAVORD Report No. 2965 1 April 1953.
- (g) Jacob Savitt, A Sensitivity Test for Castable Liquid Explosives, Including Results for Some New Materials, MAYORD Report No. 2997, 22 October 1953.
- (h) R. W. Gipson, Sensitivity of Explosives, IX: Selected Physico-Chemical Data of Men Pure High Explosives, MAVORD Report No. 6130, 18 June 1958.

⁸⁰See footnote 1, page 10.

Trinitro Triazidobenzene

Comprolition: 06	Melecular Weight: - (C606N1S) 336			
NO ₂	Gaygon Rolences			
20 20.4 人	CO ₂ % -29			
N 50.0 N ₃ N ₃	CO % U.0			
0 11 - 110	Stemeity: gm/cc Crystal 1.81			
Ψ	Melting Point: °C Decomposes 131			
C/H Ratio	Freezing Paint: 'C			
Impact Sanitrivity, 2 Kg Wt:	Rolling Point: 'C			
Bureou of Mines Apparatus, cm (a) ≤ 25	Beforethe Index B			
Sample Wt 20 mg Picatinny Arsenal Apparatus, in	Refrective Index. no			
Sample Wt, mg	nº `			
	n _s			
Friction Pondulum Test:	Vocuus Stability Tost:			
Steel Shoe	cc/40 Hrs, at			
Fiber Shoe	90°C			
	— 100°C			
Riffe Bullet Impact Test: Trials	120°C			
%	135°C			
Explosions	150°C			
Porticit	130 C			
Burned	200 Green Bomb Sand Test:			
Unaffected .	Sand, gm			
Explosica Temperature: *C (a)	Sociality to Initiation:			
Seconds, 0.1 (no cap used)	Minimum Detonating Charge, gm			
*	Mercury Fulminate			
5 150	Lead Azide			
10	Tetryl			
15	1 di 1 yi			
20	Sellistic Morter, % TNT:			
	Treuzi Test, % PFIN: 90			
75°C International Host Test: % Loss in 48 Hrs	Plate Deat Test: Method			
3846 11 - 2	Condition			
100°C Heat Test:	Confined			
% Lass, 1st 48 Hrs	Density, gm/cc			
% Loss, 2nd 48 Hrs	Brisance, % TNT			
Explosion in 100 Hrs				
Resmobility Index:	Detenation Rate:			
rion/mounty index:	Confinement			
Hyprescepicity: % 30°C, 90% RP 0.00	Condition			
Hygrescepicity: % 30°C, 90% RP 0.00	Charge Diameter, in.			
No. 4 addis.	Density, gm/cc			
Voletility:	Rate, meters/second			

Trinitro Triazidobenzena

Fregmentation Test: Shaped Charge Effectiveness, TNT = 100:				
90 mm His, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib	Gloss Cones Steel Cones Hole Volume Hole Depth			
Total No. of Fregissets: For TNT	Color: Greeni	sh-yellow		
For Subject HE	Principal Uses: (c) Ingredien	t of primer wix		
3 inch NE, M42A1 Projectile, Let KC-5: Darsity, gm/cr. Charge Wt, Ib				
Total No. of Fragments: For TNT For Subject HE	Method of Leading: Dead presses at about 42,	Fressed COO psi		
Fregment Velocity: ft/sec	Leading D salty: gm/cc At h2,000 psi	1.75		
At 9 ft At 25½ ft	Storage:			
Density, gm/cc	Method			
Blast (Relative to TNT):	Hazard Class (Quantity-Distance)		
Air: Peok Pressure Impulse	Compatibility Group Exudation	None		
Energy Air, Confined: Impulse	Qualitative Solubilities at Room 'emperature; Solvent	Solubility		
Under Water: Peak Pressure Impulse	Acetone Chloroform Alcohol Water	Readily soluble Moderately soluble Sparingly soluble Insoluble		
Energy	Compatibility with Metals:			
Undorgreund: Peak Pressure	Wet: Does not attack ire	on, steel, copper		
Impulse	Heat of:			
Energy	Combustion, cal/gm (2554		
	Burning Rate: (1	b)		
	cm/sec	0.65		

Preparation: (e)

Aniline is chlorinated to form trichlomosniline. The amino group is eliminated by the disco reaction. The resulting typ-trichlorobenzene is nitrated. This nitration is carried out by dissolving the material in warm 32% cleam, adding strong mitric acid, and heating to 140°-150°C until no trinitro trichlorobenzene (melting point 187°C) precipitates (Ref f). The chlorine groups are then replaced by azo groups. This is accomplished by adding at accompanion of the trinitro trichlorobenzene, or better, and polered substance alone, to an actively stirred solution of sodium saide in alcohol. The precipitated trinitro triasidobenzene is collected on a filter, washed with alcohol, water and dried. It may be purified by dissolving in chloroterm, allowing the colution to cool, and collecting the greenish yellow crystals (melting point 131°C with decorposition).

Origin:

This initiating explosive was first prepared in 1923 by Turek who also perfected its manufacture.

References:81

- (a) S. Helf, Tects of Explosive Compounds Submitted by Arthur D. Little, Inc., PATR 1750, 24 October 1949.
- (b) A. r. Belyaeva and A. E. Belyaeva CR a.s. USSR 52, 503-505 (1946) Chemical Abstracts 41, 4310.
 - A. E. Belyaeva and A. F. Belyaeva, Doklady Akad Mauk. USSR 56, 491-494 (1947).
 - (c) French Patent 893,941, 14 November 1944 (Chemical Abstracts 47, 8374).
- (d) A. D. Yoffe, "Thermal Decomposition and Explosion of Azides," Proc. Roy Soc A208, 188-199 (1951).
- (e) T. L. Davis, The Chemistry of Fewder and Explosives, John Wiley and Sons, Inc., New York (1943), p. 436.
 - (f) O. Turek, Chim et Ind 26, 781 (1931); German Patent 498,050; British Patent 298,981.

⁸¹See footnote 1, page 10.

Comparistons	Molecular Weight: (C ₁₅ H ₂₄ H ₈ O ₂₆)	732
Č 24.6 H 3.3 H 15.3 O 56.6	Oxygen Beloree: CO ₂ % CO %	-5:5 -32
්ස් රහර ^ප ්ස් රහර ප් රහර	Density: gm/cc Crystal	1.58
Opinicas care care	Mobing Point: °C 82	to 84
C/H Rotto 2/1/2	Freezing Point: *C	
Surgest Sassitivity, I No Wit. Burgest of Miner Apporatus, cm	Boiling Point: *C	
Sample Wt 20 mg Picatinny Arsenel Apparatus, in. 9 Sample Wt, my 24	Refrective Index. no. no. no. no. no. no. no. no. no. no	
Friction Pendulum Test:	Yacuum Stobility Test:	· · · · · · · · · · · · · · · · · · ·
Steel Shoe Unaffected	cc/40 Hrs, at	
Fiber Shoe Unaffected	90°C	
Riffe Buffet Impost Test: Trials	100°C Pure	2.45
%	120°C Specially purified	1.94
Explosions	135°C	
Porticis	150°C	
Burned Unoffected	200 Gram Bomb Sand Tost: Sand, gm	58.9
Emphalan Temporature: 'C	Sensitivity to Initiation:	
Seconds, 0.1 (nc cap used)	Minimum Detonating Charge, gm	
	Mercury Fulminate	
5 225	Lead Azide	0.30
* 10 ·	Tetryl	
15 20 20	Bellistic Merter, % TNT:	······································
	Treezi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method	
100°C Heat Test:	Condition	
% Loss, 1st 48 Hrs 1.15	Confined	
% Loss, 2nd 48 Hrs 0.75	Density, gm/cc	ζ,
Explosion in 100 Hrs None	Brisance, % TNT	`
Flammability Index:	Detenation Rate:	_
	Confinement	None
Hyprescopicity: %	- Condition	Pressed
	Charge Diameter, in.	0.5
Volentiley:	Density, gm/cc	1.56
	Rate, meters/second	7650

Tripentaerythritol Octanitrate (TPEON)

•	Desemposition Equation. Oxygen, atoms/sec	
-		
	Heat, kilocolorie/mole	23.1
	(AH, kcel/mol)	015 4- 050
	1 -	215 to 250
	Phose	Liquid
2622	Armer Plate Impact Test:	
-		
	60 mm Morter Projectile:	
ios	1	
	Aluminum Fineness	
	500-th General Purpose Bombs:	
	Plate Thirkness inches	
	rigite (frictions), inches	
240	1	
	11/4	
	11/2	
	1%	
	Somb Drop Yest:	
	T7 2000 th Sand Arman Standa	a Ramb us Canantas
	17, 2000-11 20110-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-	A marrie at Admirald;
	Max Safe Drop, ft	
	500-lb General Purpose Bomb v	es Concrete:
	Height, ft	
	Trials	
	Unaffected	
	Low Order	
•		
	1000-th General Purpose Semb	rs Concrete:
	* ·	
	1	•
	High Order	
	2632 1085 762	(Z/sec) Heat, kilocolorie/mole (AH, kcal/mol) Temperature Range, *C Phose 2632 1085 762 40 mm Marter Projectile: 50% inert, Velocity, fr/sec Aluminum Finaness 500-th General Purpose Bambs: Plate Thickness, inches 240 1 11/4 11/2 11/4 11/2 11/4 11/6 11/6 Remb Drep Yest: T7, 2000-th Semi-Armer-Piercia Max Safe Drop, ft 500-th General Purpose Bemb v Height, ft Trials Unaffected Low Order High Order

Tripentaerythritol Octanitrate (TPEON)

Fragmontation Test	Shaped Charge Effectiveness, THT = 100:		
90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib	Glass Cones Steel Cones Hole Volume Hole Depth		
Total No. of Fragments: For TNT	Color: White		
For Subject HE 3 inch HE, M42A1 Projectile, Let KC-3: Density, gm/cc Charge Wt, ib	Principel Uses: High explosive and as possible plasticizer for nitrocellulose		
Total No. of Fragments: For TNT For Entire ME	Method of Leeding: Cast or pressed		
Fregment Velocity: ft/sec	Leeding Deselty: gm/cc Pressed at 60,000 psi 1.565		
At 9 ft At,25½ ft Density, gm/cc	Storage: Method Dry		
Stast (Relative to TNT):	Hazard Class (Quantity-Distance)		
Air: Peak Pressure Impulse Energy	Compatibility Group Exudation None		
Air, Confined:	Hygroscopicity, Gain or Loss in Wt, 1:		
Impulse	Time, Hrs		
Under Weter: Peak Pressure Impulse	<u>40 70 90</u> 24 -0.008 +0.01 +0.0		
Energy	144 -0.04 -0.03 -0.02 192 -0.04 -0.02		
Underground: Peak Pressure Impulse	216 -0.004 -0.01 +0.03 Solubility:		
Energy	Solvent Solubility		
	Water Insoluble Alcohol Soluble Chloroform Soluble Acetone, hot Very soluble Benzene, hot Very soluble		

Tripentaerythritol Octanitrate (TPEON)

Compatibility With Other High Explosives:

100°C Varuum Stability Test:

	NIN	PETN	RDX	TPEON
ml gas/40 hrs, 5 gm sample	0.14	2.15	0.39	2.45
ml gas/40 hrs, 5 gm sample of 50/50, TPEON/HE	1.89	1.71	2.32	

Dipentaerythritol Hexanitrate (DPENN)-TPECN Fusions:

* TPBON	\$ DPERN	Solidification Time, Days	MP, °C
100	o	_	83
95	; 5	3	68
90	10	3	69
80	20	5	73
50	50	30	60 (Butectic)
20	80	5	63
10	90	3	69
0	100		73

Preparation:

(a)

Twenty grams (0.054 mol) of nitration grade tripentserythritol (TPE) (99%) minimum purity) were slowly added, with stirring, to 160 gm (2.55 mol) of 99% nitric acid at a temperature of -25° to 0°C. On equivalent weight basis, this quantity of 99% nitric acid corresponds to an excess of 6.3 times the TPE used. After addition of the TPE, the reaction mixture was stirred for about one hour at 0° to 5°C and poured into eight times its volume of cracked ice. The product, when allowed to stand overnight, was crushed under water; filtered with suction; and washed copiously with water. It was then treated twice with about 5 times its weight of a 1% ammonium carbonate solution, stirred for several hours, filtered and washed with water until the final washings were neutral to litrus. The final product was washed successively with 50 carach of ethanol and ether. The material dried in air weighed 37.8 gm or 96% of theory based on TPE. It had a melting range of 71° to 74°C. Crystallization of the crude TPEON from chloroform was found to be the most suitable method of obtaining pure TPEON.

Omigin:

TPEON prepared by the reaction of tripentaerythritol and 99% nitric acid at 0° to 10° C was reported by Wyler in 1945 (J. A. Wyler to Trojan Powder Company: U.S. Patent 2,389, 228, 20 November 1945).

Tripentaerythritol Octanitrate (TPEON)

References: 82

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 - (c) S. D. Brewer and H. Henkin, The Stability of PETM and Pentolite, OSRD Report No. 1414.
- (d) E. Berlow, R. H. Barth and J. E. Snow, <u>The Pentaerythritols</u>, ACS Monograph No. 136, Reinhold Publishing Corporation, New York, 1958.

⁸²See footnote 1, page 10.

Composition:	Melecular Weight:	81		
% TNT 80	Oxygen Belence:			
	CO, %	-77 -38		
Aluminum 20				
	Density: gm/cc Cast	1.72		
	Molting Faint: *C			
C/H Ratio	Freezing Point: *C			
Impact Sensitivity, 2 Kg Wt: Burecu of Mines Apparatus, cm 85	Boiling Point: °C			
Sample Wt 20 mg	Refrective Index, no			
Picotinny Arsenal Apparatus, in. 13 Sample Wt, mg 16	n≗			
Somple VII, III	n _s			
Friction Pendulum Test:	Vecuum Stebility Test:			
Steel Shoe Unaffected	cc/40 hirs, at			
Fiber Shoe Unaffected	. 60.€			
Riffe Bullet Impact Test: Trigis	100°C	0.1		
•	120°C	0.2		
% Explosions 60	135°C			
Partials 0	150°C	0.8		
Burned 0	200 Gram Bomb Sand Test: Sond, gm			
Unaffected 40				
Explosion Temperature: 'C	Sensitivity to Initiation:			
Seconds, 0.1 (no cap used) 610	Minimum Detonating Charge, gm			
1 520 5 December 1/20	Mercury Fulminate			
5 Decomposes 470	Lead Azide	0.20		
10 465	Tetryl	0.10		
15 20	Ballistic Morter, % TNT: (a)	124		
	Trousi Test, % TNT: (b)	125		
75°C International Heat Test:	Plate Dest Test: (c)			
% Loss in 48 Hrs	Method	В		
160°C Heat Test:	Condition	Cast		
% Loss, 1st 48 Hrs	Confined	No		
•	Density, gm/cc	i.75		
% Loss, 2nd 48 Hrs	Brisonce, % TNT	93		
Explosion in 100 Hrs	Decemetion Rate:			
Floremobility Index: 100	Confinement None	None		
	Condition Cast	Pressed		
Hygrescopicity: % 30°C, 90% RH 0.00	Charge Diameter, in. 1.0	1.0		
	Density, gm/cc 1.71	1.72		

Beaster Sensitivity Test: Condition	(d)	Cast	Decomposition Equation: Oxygen, atoms/sec		
Tetryl, gm		100	(Z/sec)		
Wax, in. for 50% Detanation 0.58		Heat, kilocalorie/mole			
· · · · · · · · · · · · · · · · · · ·	gilon	0.70	(AH, kcai/mol)		
Wox, gm		1.75	Temperature Range, *C		
Density, gm/cc		1.17	Phase		
Heat of: Combustion, cal/gm	(e)	4480	Armer Plate Impact Test: (e)	
Explosion, cal/gm		1770	60 mm Merter Projectife:		
Gas Volume, cc/gm			5C% Inert, Velocity, ft/sec	509	>1100
Formation, cal/gm			Aluminum Fineness	100	12
Fusion, col/gm					
			500-lb General Purpose Bernb	: :	
Specific Heat: cal/gm/°C At -5°C	(b)	0.23	Plate Thickness, inches	Trials	≸ Inert
Density, gm/cc		1.74	1	0	
Dension, Sm/cc		2014	11/4	• 6	100
At 20°C		0.31	11/2	6	33
			13/4	0	33
Burning Rate: cm/sec			Sorub Drop Test: (e)		
Thormai Conductivity: cal/soc/cm/*C Density, gm/cc	(b)	11 x 10 ⁻¹⁴	17, 2000-tb Semi-ArmsPierc	ing Somb vs	Concrete:
Coefficient of Expension:			Max Safe Drop, ft		
Linear, %/°C			500-lb General Purpose Bomb	vs Concrete	12
Volume, %/°C			41.544.6	Seal 4,000	Seal 5.000
			T .		
Hardness, Mahe' Scule:			Tricls	34 ~~	14
			Unaffected	32	14
Young's Modulus:	(b)		Low Order	0	0
E', dynes/cm²	. •	6.67 x 10 ¹⁰	High Order	2	0
E. Ib/inch²		0.97 x 10 ⁶			
Density, gm/cc		1.72	1000-lb General Purpose Semi) VI Contril	
			Height, ft		Seal 5.000
Compressive Strongth: lb/ir	rch² (b)	2340	Trials		24
Density, gm/cc		1.75	Unoffected		23
		.	-		
Vepor Pressure: "C mm	Mercury		Low Order		0
C mm	rwercury		High Order		1

Fragmentation Test:	X	Shaped Charge Silectiveness, THY = 1	190:
90 mm HE, M71 Projectile, Let WC	9 1:	Glass Cones Steel	Cones
Dercity, sm/cc	1.71	Hole Volume	
Charge Wt, #	2.272	Hole Depth	
Total No. of Fragments:			
For TNT	ሃወ3	Color:	Gray
For Subject HIE	616		
3 inch HE, M43A1 Projectile, Let KC	.E.	Principal Vers: GP bombs	
Density, gm/cc	1.75		
Charge Wt, Ib	0.914		
Yatul No. of Fragments:			
For TNT	514	Method of Londing:	Cast
For Subject HE	485		
		Leeding Dentity: 5m/:x	1.65-1.72
regment Velocity: ft/sec At 9 ft	2460		
At 25% ft	2460 2460	Storees:	
Density, gm/cc	1.72		
		Method	Dry
feet (Relative to TNT):	(f)	Hazard Class (Quantity-Distance)	Class 9
Aim		Compatibility Graup	Group I
Peak Pressure	110		Group 1
Impulse	115	Exudation	
Energy	119		
Air, Confined:		Preparation:	
Impuise	130	Tritonal is prepared by adding	TMT and
Under Weber:		aluminum senerately to a steem-	criteted meli
Paak Pressure	105	kettle equipped with a stirrer. the kettle and mixing of the ine	nesting of redients em
Impulse	118	continued until all the TMT is	elted. When
Energy	12.9	the viscosity of the mixture is satisfactory (about 85°C), the t	ritonal is
Underwend:		poured into projectiles or bombs	the same as
Peck Pressure	117	TAT.	
Impuise	127	1	
Energy	136		
спенду	136		

Origin:

The Addition of aluminum to increase the power of explosives was proposed by Recales in 1899 and patented by Roth in 1900 (German Patent 172,327). Some recent studies, directed towards establishment of the optimum amount of aluminum in the TET/Aluminum system, have shown that (1) the blast effect increases to a maximum when the aluminum content is 30% (Ref g); the brisance, as measured by the Sand Test, passes through a maximum at about 17% aluminum (Ref h); in Fragmentation Tests, no maximum is observed, additions of aluminum causing a decrease in efficiency over the entire range from 0% to 70% aluminum (Ref i); and (4) the rate of detonation of cast charges is continuously decrease? by additions of aluminum up to 40% (Ref j). For all practicel purposes it is concluded that the addition of 18% to 20% aluminum to TET improves its performance to a maximum. This conclusion is in agreement with that of British workers who measured performance of aluminized TWT-mixtures based on extensive Lead Block Test data (Ref k).

Tritonal, consisting of 80% TWT and 20% aluminum, was developed and standardized in the United States during World War II for use in bombs.

References:83

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 - (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (4) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
 - (e) Committee of Div 2 and 8, MDRC, Report on HBN and Tritonal, OSRD Fo. 5406, 31 July 1945.
- (f) W. R. Tomlinson, Jr., Elast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
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- (i) W. R. Tomlinson, Jr., <u>Develop New High Explosive Filler for AP Shot</u>, FATR No. 1380, Second Progress Report, 12 January 1944.
- (j) L. S. Wise, Effect of Aluminum on the Mate of Detonation of THT, PATR No. 1550, 26 July 1945.
- (k) Armament Research Dept, The Effect of Aluminum on the Power of Explosives, British Report AC-6437, May 1944 (Explosives Report 577/44).

⁸³See footnote 1, page 10.

Tritonal, 80/20

(1) Also see the following Picatinny Arsenal Technical Reports on Tritonal:

0 3 ½ 5 6 I 8 1530 1693 1444 1635 1956 1737 2138 1560 2353 2127

Composition:		Melecular Weight:	261		
ж них	70.0	Oxygen Belerce:			
Nitrocellulose (13.15% N)	15.0	CO ₂ %	-26		
Mi troglycerin	10.7	co %			
2-Nitrodiphenylamine	1.3	Beneitus om /cc Proposit	1 70		
Triacetin	3.0	Density: gm/cc Pressed 1.72 Melting Point: *C			
C/H Ratio					
		Freezing Point: *C			
Import Sensitivity, 2 Kg Wt: Bureou of Mines Apparatus, cm		Boiling Point: 'C			
Sample Wt 20 mg Picatinny Arsenal Apparatus, in.		Refrective Index, no			
Sample Wt, mg		n <u>B</u>			
• • • •		n _∞			
Friction Pendulum Test:		Vocuum Stability Test:			
Steel Shoe	Unaffected	cc/40 Hrs, at			
Fiber Shoe	Unaffected	90°C	****		
Rifle Builet Impact Test: Trials		100°C	1.29		
		120°C 29 hours 1			
% Explosions		135°C			
Portiols		150°C			
Burned		200 0 0 1 1			
		200 Gram Bomb Sand Test:			
Unaffected		Sand, şim	66.4		
Explosion Temperature: "C		Sensitivity to Initiation:			
Seconds, 0.1 (ric cap used)		Minimum Detonating Charge, gm			
1		Mercury Fulminate	****		
5		Leod Azide	0.30		
10		Tetryl			
15 20		Sellistic Morter, % TNT:			
		Treezi Test, % TNT:			
75°C International Heat Test: % Loss in 69 Hrs		Plate Dent Test:			
M F099 III V 2 L112		Method			
90 °C Heat Test:		Condition			
% Loss, 1st 48 Hrs 0.28		Confined			
% Loss, 2nd 48 Hrs	1.12	Density, gm/cc			
Explosion in 100 Hrs	None	Brisance, % TNT			
		Detenation Rate:			
Flommobility Index:		Confinement			
		Condition			
Hygroscopicity: %		Chorge Diameter, in.			
N. 1 . 1911.		Density, gm/cc			
Volatility:		Rote, meters/second (calculated)	8500		

^{*}See footnote c. following page.

Veltex No. 448*

Secretar Sensitivity Test:		Decomposition Equation:		
Condition		Oxygen, atoms/sec (Z/sec)		
Tetryl, gm		Heat, kilocalorie/mole		
Wax, in. for 50% Detonation		(AH, kcal/mol)		
Wax, gm		Temperature Range, *C		
Density, gm/cc		Phase		
Heat of:	. 0050	Armor Plate Impact Test:		
Combustion, cal/gm	2359			
Explosion, cal/gm	1226	60 mm Morter Projectile:		
Gas Volume, cc/gm		50% Inert, Velocity, ft/sec		
Formation, cal/gm		Aluminum Fineness		
Fusion, cal/gm				
		500-lb Ganeral Purpose Bombs:		
Compression at Rupture: \$	8.26	Plate Thickness, inches		
Work to Produce Rupture:				
ft-1b/inch ³	9.62	114		
1 C-10/ I Ren	9.02	11/2		
		134		
Surning State:		174		
cm/sec		Samb Drue Test:		
Thermal Conductivity: col/sec/cm/°C		T7, 2000-ib Somi-Armor-Piercing Bomb vs Concrete:		
		Max Safe Drop, ft		
Coefficient of Expansion:		Max sale Drap, It		
Linear, %/°C		500-lb General Purpose Bomb vs Concrete:		
Volume, %/*C		Height, ft		
		Trials		
Herdness, Mehs' Scale:		Unaffected		
		Low Order		
Young's Modulus:	. 10	High Order		
	.24 x 10 ¹⁰			
E, Ib/inch ² C.	. 35 × 10 ⁵	1000-lb General Purpose Bomb vs Concrete:		
Density, gm/cc				
Community Strength, th/inch2	2720	Height, ft		
Compressive Strongth: Ib/inch²	2120	Trials		
		Unaffected		
Voper Pressure:		Low Order		
°C mm Mercury		High Order		
*Name assigned by Dr. Mar. M. Jo of PA; based on original develonames H. Veltman.		,		

Veltex No. 448

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:		
90 mm HE, M71 Projectile, Let WG-91: DenLity, gm/cc Charge Wt, th	Glass Cones Steel Concs Hole Volume ' Hole Depth		
Total No. of Fragments: For TNT	Color: Orange		
For Subject HE 3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib	Principal Uses: High mechanical strength machinable explosive		
Total No. of Fragments: For TNT For Subject HE	Method of Loading: Pressed		
Fragment Velocity: ft/sec At 9 ft	Leading Density: gm/cc At 6,700 psi 1.72		
At 25½ ft Density, gm/cc	Storage: Method Dry		
Bleat (Relative to TNT):	Hazard Class (Quantity-Distance)		
Air: Peak Pressure Impulse Energy	Compatibility Group Exudation None Machinability Excellent		
Air, Confined: Impulse			
Under Weter: Peak Pressure Impulse Energy			
Underground: Peak Pressure impulse Energy			

Preparation:

The preparation of this class of explosive compositions is illustrated by the method used for Veltex No. 448: Place 675 cc of water in a slurry kettle equipped with an agit tem. Add 5.85 gm of 2-nitrodiphenylamine and agitate for several minutes to obtain dispersion. Then add 93.7 gm of water-wet nitrocellulose (dry weight 67.5 gm) in small portions. Prise the temperature to 48°C and maintain this temperature, but continue the agitation. A mixture of 48.2 gm of nitroglycerin and 13.5 gm of triacetin is added over a 5-minute period, with the mixing continuing for an additional 10 minutes at 48°C. The INX (350 gm) is added over a 5-minute period with agitation continued for 30 minutes at 48°C. The slurry is cooled to room temperature and filtered. The filter cake is dried to a moisture contant between 8% and 12%. The incorporation of this mix is completed by rolling 50 gm portions at a temperature of approximately 90°C. The finished coll d is then preheated on a heat table at 60°C. Increments of 25 gm each are pressed at 670c psi for four minutes at 71°C. A cylinder is then built up by pressing together four 25 gm increments for a dwell time of 15 minutes.

Origin:

Veltex is the name given to a series of closely related nitrocellulose compositions prepared in 1957 at Picatinny Arsenal by the solventless process used for propellants. These compositions all contain a high percentage of solid high explosive. They were investigated to determinate the suitability of the Holtex type explosive developed by Hispano Suiza of Switzerland, France and Spain, but for which the composition was not reported (Ref a). Compositions similar to Veltex No. 448 and containing 60% to 80% HMX, with either nitroglycerin or triethyleneglycol dinitrate as colloiding agent for nitrocellulose, have also been prepared. In general these compositions showed lower heat stability than that of conventional high explosive compositions.

Reference: 84

(a) U.S. Air Intelligence Information Report IR-269-55, Holtex--Hispano Suiza Explosive, 4 May 1955.

⁸⁴See footnote 1, page 10.

(AMCRD-TV)

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No. Ittle Mine 706-

No. APICP 706-	<u>litle</u>	No. AMCP 706-	Title
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104	*Value Engineering		Design
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111	cepts and Analysis of Mranyrement Data	213(5)	Fuzes, Proximity, Electrical, Part Three (U)
***	Experimental Statistics, Sociion 2, Analysis of Enumerative and Classificatory Data	214(5) 215(C)	Fuzes, Proximity, Electrical, Part Four (U) Fuzes, Proximity, Electrical, Part Five (U)
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115	Environmental Series, Part One, Basic Environ-		Characteristics (REPLACES -246)
116	mental Concepts *Environmental Series, Part Two, Basic Environ-	244	Ammunition, Section 1, Artillery Ammunition General, with Table of Contents, Glossary,
	mental factors		and Index for Series
120	*Criteria for Environmental Control of Mobile Systems	245(C)	Ammunition, Section 2, Design for Terminel Effects (U)
121	**Packaging and Pack Engineering	246	*Ammunition, Section 3, Design for Control of
123	*Hydraulic Fluids		Flight Characteristics (REPLACED BY -242)
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	Material	***	Components of Artillery Armunitian
133 134	*Maintainability Engineering Theory and Practice	250 251	GunsGeneral Muzzle Devices
135	Mr ntaine. Tity Guide for Design Inventions, Patents, and Related Matters	252	Gun Tubes
136	Ser mechanisms, Section 1, Theory	255	Spectral Characteristics of Muzzle Flash
137	Servomechanisms, Switton 2, Measurement and	260	Automatic Weapons
138	Signal Converters Servomechanisms, Section 3, Amplification	270 280	Propellant Actuated Devices Design of Aerodynamically Stabilized Frie
139	Servomschantsms, Section 4. Power Elements and		Rockets
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187	Military Pyrotechnics, Part Three, Properties		Molume I. Munitions and Weapon Systems (U)
100	of Materials Used in .yrotechnic Compositions	336(SRD)	*Design Engineers Suclear Effects Manual, Yolume II, Electronic Systems and Logistical
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